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IN THIS ISSUE:

Helicopters

VOLUME VI 3 1951

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Review of World Aviation

Volume VI — No 3 — 1951

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Contents

HELICOPTERS

Spotlight on the "Egg-Beater" 127
Helicopter Production BARTRAM KELLEY, BUFFALO, N.Y. 129
Mid Century Rotary Wing Aircraft — A Review 132
"Bigger and Better" — Hughes Makes Helicopter News 137
Downtown Heliport 138
How to Fly a Helicopter N.O. SEFELDT, VÄSTERAS 139
Preparing Commercial Helicopter Services N.E. ROWE, B.E.A. 142
Automatic Control for Helicopters 147
Young Mr. Hillercopter S. BANGS, LOS ANGELES 149
The "Egg-Beater" goes to War 152
What's in the Air ? 154
1951 Aviation Prospects (cont.) 156
The Mind of Mr. Reader 158
H-5 Rotor Anti-Icing System E.F. KATZENBERGER, BRIDGEPORT 159
En Route Navigation Systems and Air Traffic Control T. v. HAUTEVILLE, STUTTGART 161

Front Cover :

A Sikorsky HO3S-1 of the U.S. Navy (H-5 in the USAF, S-51 in civilian use) undergoing tests with a Navy-developed automatic pilot for helicopters.

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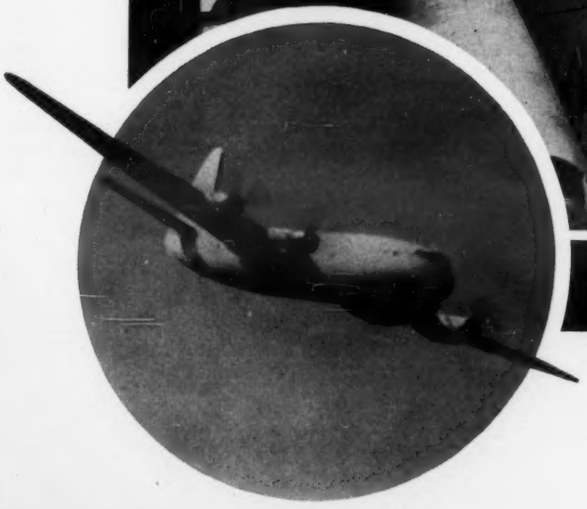

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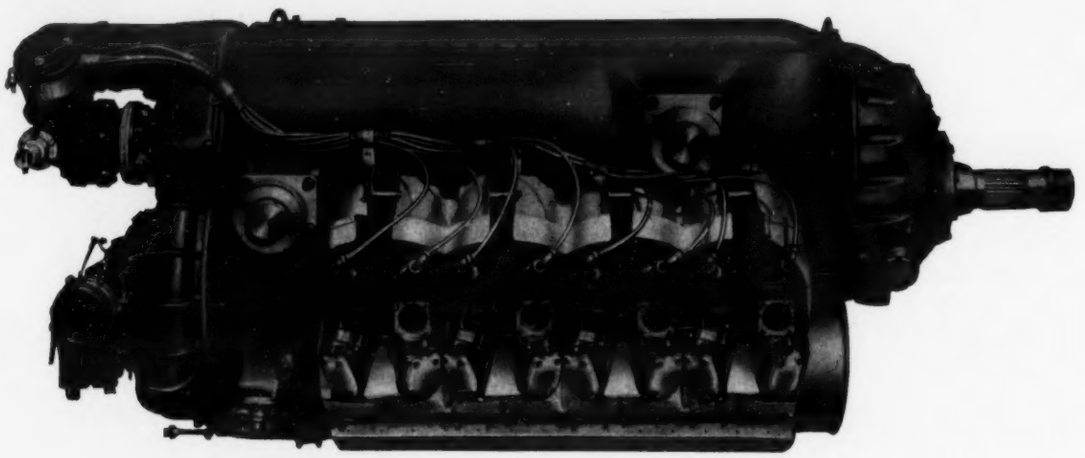

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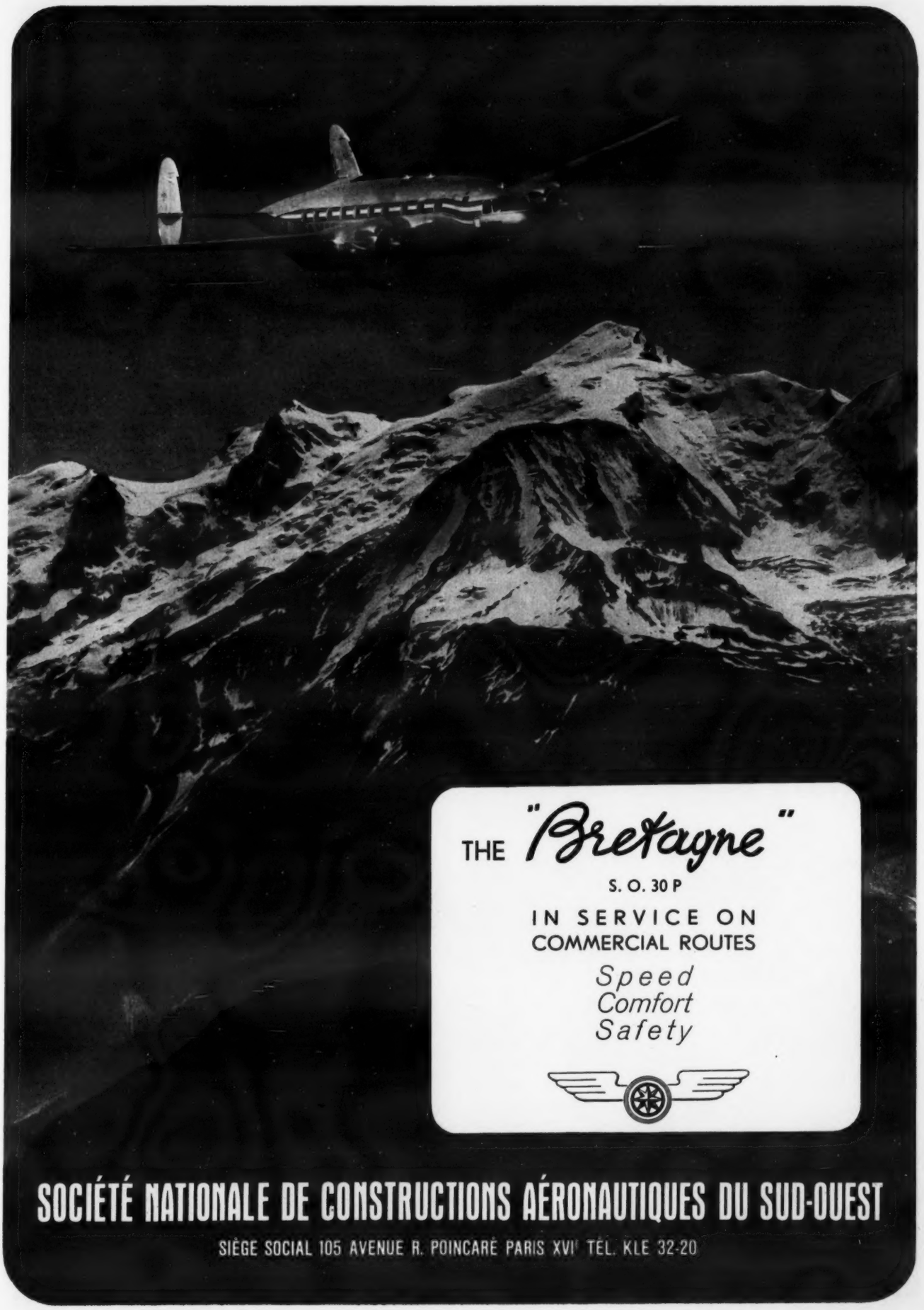

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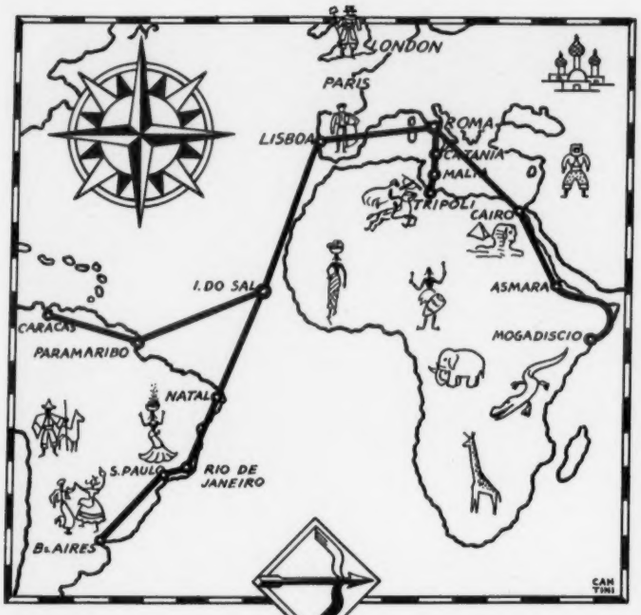

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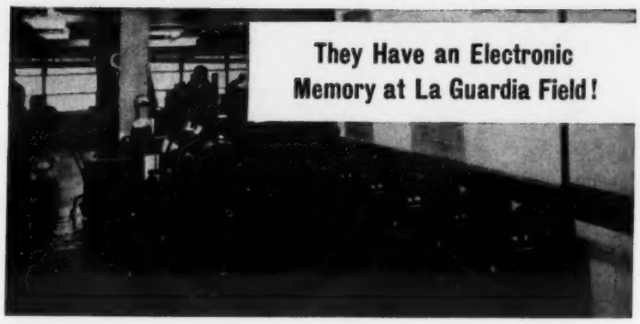

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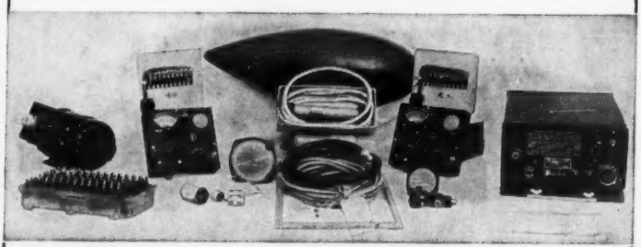

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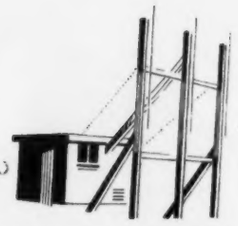

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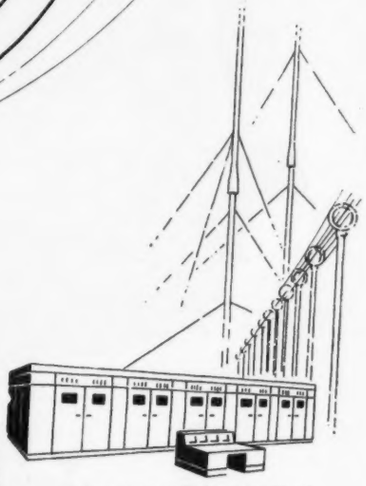

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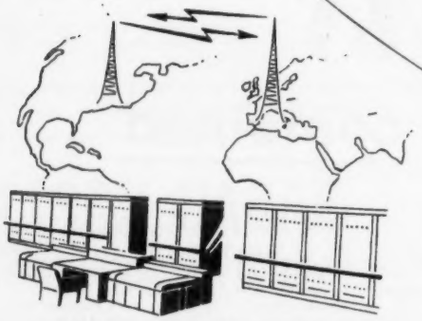

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Helicopters

Spotlight on the "Egg-Beater"

Why a Helicopter Issue?

When the Bendix Helicopter Corp. (ultimately known as Helicopters Inc.) went into liquidation early in September 1949 after a life of five years, it was so to speak in full possession of its financial faculties. Why then, being still solvent, did it throw in its hand? Janson, the Vice-President of the Company, gave a brief, but pointed answer to this query: *There's "nothing doing" in the helicopter market at the present time.*

A few months earlier the Landgraf Helicopter Co. had also withdrawn from production and leased its plant to "Rick Helicopters Inc." From the auctioning of its helicopter prototype which had been developed for the USAF (but had been damaged during its trials) the Landgraf Co. realised the magnificent sum of $50. And nothing more has been heard to this day of its successors, Rick Helicopters Inc.

Two examples chosen at random—but typical of the overwhelming majority of the helicopter constructors who have been active during the past decade. Hundreds of small firms, far less known than the above-mentioned companies, came, saw—and disappeared. Whether or not they had other reasons for closing down, all without exception were convinced that the day of the mass-produced helicopter—even the veriest technical masterpiece—was not yet, in other words that the helicopter could not provide the "bread and butter" business to keep alive that voracious monster, the aircraft industry. Moreover, even three or four years ago, the helicopter was a good deal less confidence-inspiring even than it is today. Here, as in the aircraft world in general, development has been by leaps and bounds—rather like young dogs who live through seven "dog" years in a single human year. In helicopter construction development was if anything even more precipitate. On 6th May 1941, that is, a bare ten years ago, Igor Ivan Sikorsky, the gifted American designer of Russian origin, set up a world endurance record in his first helicopter model by hovering for 1 hr. 32 min. 26.1 sec. above the tree-tops of Sniffen's Point (near Stratford, Connecticut).

There you have the astounding development rate of the rotary-wing aircraft, known affectionately to the Americans as the "egg-beater."

And today? Carried along by the rising market in aircraft shares, the helicopter has risen within a few months to a kind of "private boom," though not on the New York Stock Exchange. High finance has so far taken but little notice of it. Wall Street at present quotes only two helicopter firms—not because they turn out helicopters but because their other activities make them of interest to the investor—namely United Aircraft with its Sikorsky Aircraft Division, and Bell Aircraft. But the free market has suddenly, indiscriminately favoured anything that looks in the remotest like a helicopter. In an article published on 22nd January 1951 entitled "Copter Shares Lure Speculators," Selig Altschul, "Aviation Week's" financial correspondent, speaks of a real helicopter boom. The events in Korea led to a vigorous demand in the USA for helicopter shares. Originally restricted to large concerns with quantity orders, it was soon extended to firms whose total resources consisted of a more or less completed test model with which they hoped to find favour in the eyes of the USAF. Altschul closes with the words: "The current speculative and investment interest in helicopters can prove constructive in that it does make possible additional sources of capital. At the same time, speculative excesses can prove harmful in that investor confidence may suffer at some future time when such financial assistance may be needed."

The helicopter makes its bow to Royalty. *Queen Friederike of Greece* showed great interest in the "egg-beater."

We couldn't agree more! The few serious helicopter producers will certainly not take this warning amiss, but rather endorse it in its entirety. Let us turn off the rotor for a moment and undisturbed by any extraneous noises, count up the number of economically sound helicopter producers in the world. There are just eleven of them, five in the USA, three in Britain and three in France, namely:—

USA	*Great Britain*	*France*
Sikorsky	Cierva	Bréguet
Bell	Bristol	SNCASO
Piasecki	Fairey	SNCASE
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And only four of these ten are at present engaged in quantity production—the first four Americans... Does this surprise you? The European helicopter industry (at least where its own designs are concerned) has not yet got beyond the experimental stage. These experiments, described elsewhere in this issue, are very interesting and point to a successful future, but so far there is nothing to set the calculating machines in the accounts departments working.

*

If all this is true, *why are we giving you a helicopter number?* Interavia readers can give you the answer to this question unhesitatingly: Because the *possible uses*

Helicopters

British European Airways' mail service is operated with Sikorsky S-51 helicopters.

of the helicopter today are legion, because there are a thousand-and-one jobs which no other land, water or air vehicle can undertake.

Any detailed description of the practical achievements of the helicopter would go way beyond the scope of this article. Instead of giving a lot of dry statistics, let us pass the word to one who has had practical experience. Captain Victor Armstrong, a veteran of World War II, who has been in the Korean operations as helicopter pilot in the U.S. 1st Marine Air Wing, paid a visit to the Sikorsky helicopter plant at Bridgeport (Connecticut) at the end of December 1950. An impromptu works meeting was called and he described his squadron's 200 helicopter missions, carrying wounded and in the search and rescue service. He himself had picked up, from inaccessible country, severely wounded who would certainly have perished had they been transported over Korea's rough roads by jeep or ambulance. In the unanimous opinion of the doctors 90% of the wounded evacuated by helicopter would not have survived transport on the ground. On the other hand Captain Armstrong stated: "It was unfortunate that we didn't have more helicopters there, for we had to pick and choose our wounded. Only those who were in an extremely critical condition could be helicoptered back. The others went back by conventional means."

The same elementary bases for an "analysis of the present and potential helicopter market" can be heard from any helicopter pilot, no matter what his special job is: crop-dusting, rescue service in the Arctic, mail service for large towns, short-range reconnaissance for the air forces, police patrols, oil prospecting, supplying isolated ships and lighthouses, or what you will. *The helicopter? An eminently useful, versatile vehicle with a tremendous future.* But still few in number, because after all still more or less in the "string and chewing gum" stage.

For example American Marine helicopters flew a total of 648 missions in Korea up to the end of October 1950, including search and rescue missions. In itself, a sizeable number, but compared with the 500 to 800 *daily* sorties by fixed-wing aircraft, still very modest.

The same applies to civilian operations. The Belgian air transport campany Sabena and the Belgian postal authorities appear to have achieved successful results from the mail service they opened on 23rd August, 1950. Undoubtedly it is of incalculable value that the mail helicopter can land almost in the centre of the towns served: in Brussels near the Port de Ninove tram terminus, in Libramont on the football pitch, in Antwerp on a drill ground bordering the main road. But let us not forget that this mail service was the first experiment on the continent of Europe (Sabena had been preceded only by BEA—cf. elsewhere in this issue) and that the whole operation is still carried out with just two Bell 47-D1 helicopters.

Another example—the Aviation Bureau of the New York Police Department. Early in 1950 they reported enthusiastically the rescue of a fisherman stranded in the mud of Jamaica Bay and threatened by the rising tide. The police helicopter represented the last hope and he was saved at the last moment because the helicopter's engine could be warmed up in 1½ minutes, compared with the 5 minutes required for ordinary aircraft. A striking example of the helicopter's value. But how many helicopters does the New York Police use? The grand total of three—and they are the only police in the world to use helicopters on their regular patrols.

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But enough of these examples. They have been included to warn designers and engineers not to let their enthusiasm, legitimate enough in itself, run away with them.

But now that the financial critics have had their say, it must also be admitted that paying quantity production has already started in the USA. *Sikorsky* recently received from the USAF, the Navy and the Army orders for a provisional 200 Sikorsky H-19s (for 10 troops and crew of two), and an order for 25 three-to-four seaters for the Navy. *Bell* is building over 100 Bell H-13Bs for the Army and the Naval Air Arm. From *Piasecki*—whose net profit rose from $4,178 in 1947 to $105,946 in 1949—the Naval Air Arm has ordered over a hundred Piasecki HUP-1 "Retrievers." *Hiller's* turnover between January and September 1950 exceeded that for the similar period of 1949 by a full 330%. This relatively small concern had delivered over 100 Hiller 360s up to the middle of November 1950 and even before the recent large rearmament orders were placed had a backlog of orders amounting to $1,000,000.

What of the export business? Up to 1949 the only makes of helicopter really known in countries outside America were Bell and Sikorsky, and these continue to be the most popular. For example the British firm of Westland Aircraft Ltd., Yeovil (Somerset), who had been building the four-seater Sikorsky S-51 under licence since 1947, recently also acquired the licence for the ten-to-twelve seater S-55, for which the Navy is already said to have placed orders.

Of late, however, Hiller has also been making remarkable and rapid progress in overseas markets. The firm has agents in France, Switzerland, Belgium, Italy, French and British West Africa, Indochina and Madagascar. Some indication of the extent of its activity is given by the export orders it received during December 1950 and January 1951—the newly-formed French company "Helicop Azur," has ordered 3 Hiller 360s for its service to the French Riviera; "Helicop Afrique" 3 Hiller 360s for pest control in North Africa; the British firm, Pest Control Ltd., 3 Hiller 360s for supervising cotton plantations in the Sudan; and the Egyptian Ministry of Agriculture 5 Hiller 360s for crop-dusting in the Nile Delta.

*

The four leading American firms thus have no cause for complaint. Their business is doing well. Why? Because they chose their "parents" wisely. Sikorsky belongs to the mighty United Aircraft Corp. who could afford to support a helicopter division even if its activity were limited for years to the construction of prototypes. Bell has Army contracts for high speed experimental aircraft and guided missiles as well as considerable sub-contracts. Why should it not also put helicopters in its "shop window," as a hobby and against a boom in years to come? And there is no need to have any anxiety about Piasecki, even if it had a much smaller backlog of orders than it has today (over $12,000,000), for Piasecki capital is provided for the most part by the group which is also at home on the boards of McDonnell Aircraft Co., Motors Reaction Inc., and Eastern Air Lines. You have guessed—Laurence S. Rockefeller, President of the Rockefeller Bros. Inc. finance company, which does not often make a bad bet.

All of which goes to prove once more that not only technical skill, commercial vision and idealism are required to ensure the prosperity of a new branch of industry, but also the capacity to hold on, conferred by well-filled coffers.

Helicopter Production

BY BARTRAM KELLEY, CHIEF HELICOPTER ENGINEER, BELL AIRCRAFT CORPORATION

The Nature of the Problem

Because the helicopter is a flying machine it is usually thought of as an eccentric first cousin to the airplane. This blood relationship may be appropriate from the point of view of the passenger interested only in air transportation, or the farmer who wants his crops sprayed with chemicals, but in the mind of the designer and manufacturer the machine is by no means a first cousin of the airplane : the relationship is more distant.

The designer will find that many of his draftsmen came from the automobile industry; and the helicopter manufacturer will set up an elaborate machine shop, a transmission gear shop, a small assembly area, and a modest sheet metal shop.

On the other hand, the manufacturer of light airplanes would have a comparatively large assembly area, and would leave all gear fabrication to the engine producer.

To illustrate the point, we shall consider the weights of the various components of the Bell Model 47 helicopter, assuming the empty weight to be 1516 pounds.

We shall study only this conventional torque-driven, piston-engined, three-place helicopter in order to get one clear picture from which comparisons can be made. The figures quoted are not exact but are representative of one stage in development of production techniques.

Table: Model 47 Three-Place Helicopter. Empty Weight 1516 lbs.

Category A: Mechanical Parts to be Designed and Built by the Manufacturer.

Main Rotor System	250 lbs.	39% of Empty Weight Requires 62% of Design Talent Represents 55% of Total Cost to Customer.
Tail Rotor System	34 lbs.	
Engines Controls and Cooling System	19 lbs.	
Transmission System	119 lbs.	
Fuel and oil Systems	51 lbs.	
Flight Controls	116 lbs.	
Total	589 lbs.	

Category B: Parts already familiar to the Airplane Industry.

Fuselage	292 lbs.	29% of Empty Weight 26% of Design Talent 18% of Total Cost
Landing Gear	110 lbs.	
Seats and Furnishings	32 lbs.	
Total	443 lbs.	

Category C: Parts to be purchased and installed by Manufacturer.

Engine and Accessories	341 lbs.	31.5% of Empty Weight 12% of Design Talent 27% of Total Cost
Radio and Electrical Instruments and Miscellaneous	100 lbs.	
	52 lbs.	
Total	493 lbs.	

Note that the largest percentage by weight consists of mechanical parts under Category A. These are the components which make a helicopter different from its competitors. They form the core of the design and are mostly unfamiliar to airplane people.

Whereas the rotor and transmission systems and swashplate controls are obviously peculiar to the helicopter, perhaps the other items included in Category A require some explanation.

The throttle, cooling, fuel and oil systems are quite different from their airplane counterparts. For example, a light, powerful cooling fan is required because the engine is completely submerged and no ram air is available for cooling during hovering flight.

The fuel and oil systems also have their helicopter peculiarities; and the throttle bears no resemblance to an airplane throttle. (The carburetor butterfly must be opened not only when the collective pitch lever is twisted, but also when the lever is raised. This requires a synchronizing cam mechanism.)

The foregoing example is merely an indication of the many differences between fixed and rotary wings. Even the airspeed indicators and tachometers cannot be taken from an airplane supply catalogue, but are specially designed for helicopters.

Production Methods

The five pictures illustrate production methods developed at Bell Aircraft Corporation at Buffalo, New York, USA during a period when approximately 100 helicopters per year were turned out. This Corporation has pioneered in an overall helicopter

Wooden rotor blades nearing completion. Scales in background are for accurate weighing and balancing blades in pairs.

Conventional milling machines with standard fixture technique. Cast aluminium transmission cases in right foreground.

manufacturing operation and has worked out its own production methods.

Later, after one or two hundred pieces of each component were made, subcontracting manufacturers were enlisted in order to leave Bell machinery free for further development.

This programme started with experiments, occasional false steps and extensive training of men; it ended with a recipe for quantity production.

Figure 1 shows wooden rotor blades nearing completion. The men are doing hand operations prior to machining holes in the butts, covering with fiberglas cloth, and fitting sheet steel protective pieces over the leading edge. Scales in the background are for accurate weighing and balancing the blades in pairs.

The method of construction was developed by Arthur M. Young, former Bell Chief Helicopter Engineer, and is described in U.S. Patent 2,470,056. Pieces of birch, spruce and balsa are cut in matched pairs, one piece for each blade. They are then glued together to form a large wooden block in which a steel core piece is loosely embedded.

The wooden block is cut to approximately airfoil contour by a routing saw with ganged blades and dados, after which accurate hand finishing is done to templates. The blades have then reached the stage shown in *Figure 1*. The hand work is not excessive when compared with the riveting and other operations on a metal airplane wing.

Figure 2 shows conventional milling machines with standard fixture techniques. In the right foreground are cast aluminium transmission cases. These require accurate boring and locating of holes to house shaft and gear bearings and to match adjacent castings with oil-tight fits. Problems of distortion and proper aging had to be solved. To the left centre are hub yokes, which retain the main blades and withstand full rotor lift and torque. Here the forgings are faced and the large holes in the centre are being machined. In the background are other main rotor parts.

Figure 3 shows one typical gear from the transmission. This internal gear has 32 accurate slots around its periphery for accommodating free-wheel rollers. The shaper is cutting the internal gear teeth. Later the part will be case-hardened by nitriding, after which both the internal gear teeth and the external slots will be ground.

Of course, this gear is expensive when produced in small quantities, but it lends itself well to automotive mass production, like so many of the items in Category A of the Table.

A typical gear from transmission. It has 32 slots for accommodating free-wheel rollers.

Figure 4 shows an instructor's class in assembly of the transmission. The photograph shows the free-wheeling gear of Fig. 3 as well as the centrifugal clutch shoes, the planetary assemblies, cases, bearings, and hardened and ground spiral bevel gears.

The assembly techniques are familiar to engine manufacturers and present no unusual problems. Special tools are used to insert ball bearings without damage, gear meshes must be checked for backlash and alignment, and the whole transmission is run in under full power before being installed on a helicopter.

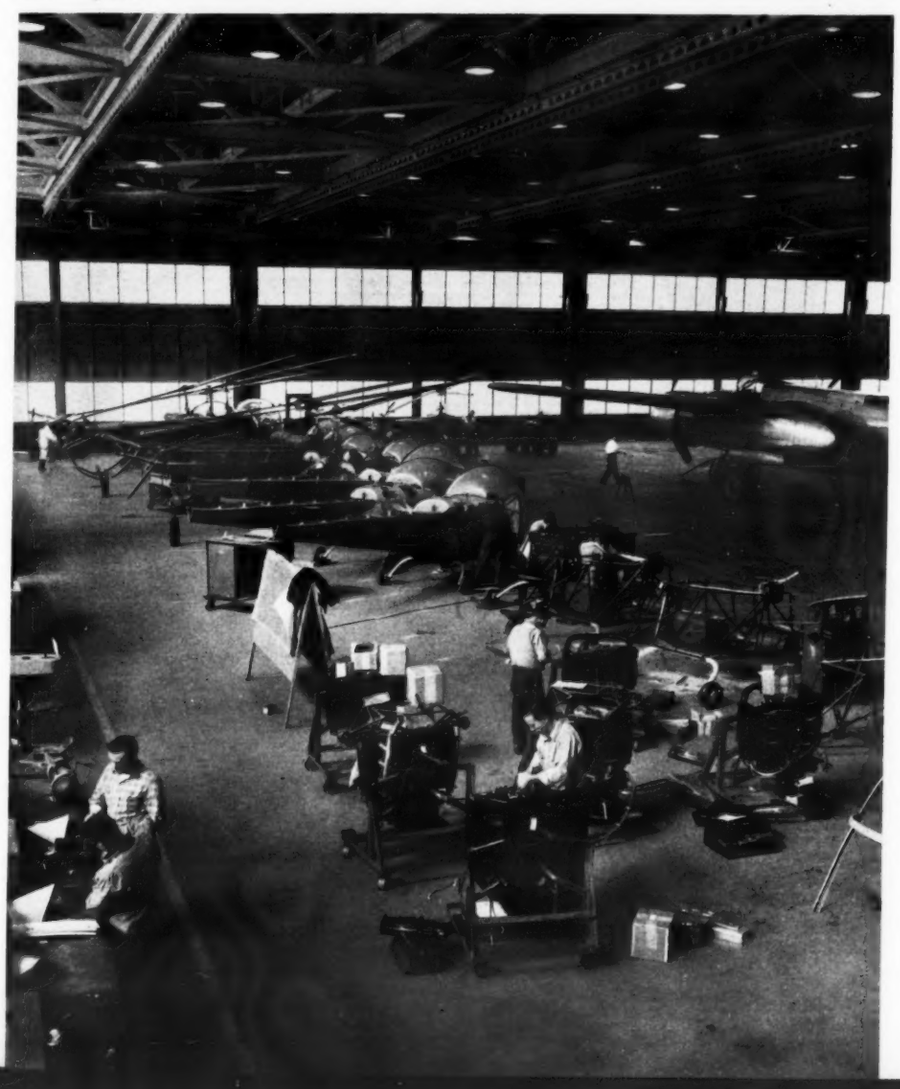
All this work can be done far from the final assembly line, and it lends itself well to production methods with each worker specializing in one or two operations.

Figure 5 shows an early helicopter production line. Note how close together the machines are standing, and how much less space is required than for a similar number of small airplanes.

Even in very high production the assembly line would probably not be much longer than

Instructor teaching a class how to assemble a transmission.

An early helicopter production line. Much less space is required than for the assembly of a similar number of small aeroplanes.



this, because each helicopter spends very little time on the line.

Components such as engines, fuselages, transmissions, rotors, plexiglass pilot's compartments, tail rotors and drive shafts have all been manufactured and assembled elsewhere in the factory and are quickly brought together on the line to form the complete helicopter.

In fact, early experiments showed that at one point the assembly line actually grew smaller as the production rate increased. *Figure 5* represents a reasonable length for the line for this small helicopter.

Of course, production can be enormously increased by running any desired number of additional lines in parallel. Thus the helicopter lends itself well to mass production methods and requires much less space than the airplane.

Cost

The experiment in production of about 100 helicopters per year just described has provided modest information concerning costs. Tentative production methods for blades, transmissions and rotor hubs have been initiated, refined and paid for, but there is not yet enough evidence to indicate what the helicopter will cost in very high production when tooling is further refined and other processes developed.

Caution must be used in applying standard airframe cost analyses and production curves to the helicopter. They apply only to Category B and part of Category C in Table 1, and then in a limited way. A better comparison would be provided by a small experimental quantity of automobiles.

It is possible that in quantities of only 100 per year, the automobile might well cost more than the helicopter (if the model were changed each year). However, it cannot be concluded from this that the mass-production helicopter will ever be as cheap as a modern car.

Since the helicopter must fly, it has many highly stressed parts designed to be as light as possible consistent with safety. This means aluminium, magnesium and expensive steel alloys for raw materials. It means machining to close tolerances, heat treating and a substantial number of grinding operations. Also, inspection is thorough and high quality must be retained throughout to assure safety of flight.

These considerations have led to an estimate of at least twice the cost of a medium-priced car for helicopters in very high production quantities. This estimate, it must be understood, is only a hopeful guess but it represents a goal worth striving for.

Mid-Century Rotary Wing Aircraft

A Review

Although a model helicopter, with co-axial contra-rotating screws was designed and flown by the Frenchmen Launoy and Bienvenue before the French Revolution (1784) and the Bréguet brothers carried out manned hovering flights near the ground early in the present century (1907), it was some time before rotary wing aircraft became really practical propositions. The way was prepared by the Spanish designer Juan de la Cierva's various *autogyros*, with tractor propeller and freely rotating rotor (1922 onwards). These were followed by the first free-flight *helicopters* built by Bréguet (1936; with co-axial rotors) and Focke (1937; with side-by-side contra-rotating rotors). During the War other design principles were put into practice, such as torque compensation by tail rotors (Sikorsky), tandem rotors (Piasecki) and intermeshing rotors (Flettner), and finally jet-propulsion (Doblhoff). The latest are the *gyrodyne*s (Fairey "Gyrodyne" and Nord 1700), which use their power-driven rotors only to produce the required lift and are propelled by an airscrew. Finally, recently there has been talk of *convertoplanes*, which are designed to take off like helicopters, then tip their contra-rotating rotors in the direction of flight and fly at high speed with the aid of lift-producing wing stubs, finally landing like a helicopter or autogyro.

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Today's rotary wing aircraft include examples of all the above-mentioned design principles. The autogyro principle seems to be obsolescent and is now used only in conjunction with power-driven rotors, i.e. in the gyrodyne, and in autorotating flight by helicopters. On the other hand the convertoplane has not yet advanced beyond the design stage, and can also be ignored here. About three dozen helicopters and the two gyrodynes already mentioned are today in use, undergoing trials, or in production. They are of all sizes, from the small single-seater helicopters of Pentecost, Baumgartl etc., to Howard Hughes' XH-17 giant windmill with its rotor span of 120 ft., which is described elsewhere in this issue. A round dozen of these types is in quantity production and must therefore be regarded as *production models*.

A further two dozen rotary wing aircraft fall into the class of *experimental models*. These are not all prototypes, but include all those for which any details are known. For example, a twin-rotor, twin-engined and presumably eight-seater development of the "Omega" helicopter designed by I.P. Bratukhin (with side-by-side rotors) is being tried out in the Soviet Union, and a "Vertolet" experimental model by N.I. Kamov with co-axial rotors. The Polish Institute for Aircraft Construction (GIL), Warsaw, has developed a single-rotor 105 h.p. single-seater (with tail rotor) from a design by Zurakowsky, etc.—Finally new projects are said to be under consideration in America, e.g. there is talk of the development of a twin-rotor 2450 h.p. helicopter, the Bell XHSL-1, for the US Navy—so that our list will doubtless soon have to be added to.

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Production Models

BELL 47D-1 (USA)
Latest three-place version of the 47 type developed in 1946 with 180 or 200 h.p. Franklin engine. Usual Bell stabilisation by centrifugal weights; plexiglas full-view cabin. Over 100 47D helicopters have recently been ordered for the US Army (H-13D) and the Navy (HTL-3).

BELL 48A (USA)
Originally developed for the USAF (known as XH-12 and YH-12B), this 5 to 8-seater has also been produced in a civil "feeder-liner" version. It can be fitted with either a 610 h.p. ("Wasp") or a 810 h.p. ("Cyclone") engine; the latest version, the YH-12B, has a four-wheel undercarriage.

BELL 54 (USA)
Two-seater developed for the USAF (service designation YH-15) for close reconnaissance, observation and communications. Of more robust construction than the 47D, it also has gyro stabilisation and a 280 h.p. engine (Continental or Franklin).

HILLER 360 (USA)
Three-seater with "inherent stability" paddle-rotor control, widespread civil and military use. The US Naval Air Arm is using it for training purposes (designation HTE-1), the USAF for its ambulance service (designation H-23A).

PIASECKI PV-3 (HRP-1) "RESCUER" (USA)
A 10-seater produced for the US Navy (first flights in 1945). Since then an all-metal version (HRP-2) has been developed for the Navy and also ordered in large numbers by the USAF (designation H-21). Fitted with a 1550 h.p. engine (Wright), the H-21 is to be employed in the Arctic rescue service.

PIASECKI PV-14 (HUP-1) "RETRIEVER" (USA)
Designed for carrier operations, the 5 to 7-seater "Retriever" is regarded as an efficient production model (speed 131 m.p.h., rate of climb over 1600 ft./min.). First helicopter to loop the loop.

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SIKORSKY S-51 (USA)
In quantity production since 1946, the 4 to 5-seater S-51 (USAF: H-5; Navy HO3S-1) is among the best-known helicopters. First civil helicopter to be certificated by the CAA and is today used on regular passenger and mail services. Licence production in Great Britain.

SIKORSKY S-52 and S-52-2 (USA)
Picture shows two-seater S-52 from which the 3 to 4-seater S-52-2 (USAF: YH-18; Navy HO5S-1) was derived. The engine in the S-52 is a 180 h.p. Franklin, in the S-52-2 a 250 h.p. Franklin. The S-52-2 also has a four-wheel undercarriage.

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SIKORSKY S-55 (USA)
This 12-seater (H-19A) developed for the USAF is today also in production for the Navy (as the HO4S-1) and the US Army (over 200 altogether). Its 610 h.p. engine is fitted obliquely in the nose.—Work is in progress on a twin-engined model, S-65 (16 to 24 passengers).

KAMAN K-255 (USA)
Three-seater version of a long series — three-seaters K-125A (first flight 1947), K-190, XHK-225 (230 h.p.); four-seater HOK-1 (455 h.p.); two seater HTK-1 (240 h.p.). A special version, the YH-22 is being tried out by the US Army.

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BRISTOL 171 MK. 3 (GREAT BRITAIN)
Four to five seater produced for feeder services (air taxi), reconnaissance and rescue duties. First flight by prototype (Mk. 1) in July 1947. Four Bristol 171 Mk. 3's have already flown; a group of 15 is under construction. A twin-engined model (Bristol 173 with tandem rotors) will probably fly shortly.

WESTLAND-SIKORSKY "DRAGONFLY HR MK. 1" (GREAT BRITAIN)
The British licence version of the Sikorsky S-51 in service with the Royal Navy (picture) and the RAF (as the "Dragonfly HC Mk. 2"). It is fitted with a 535 h.p. Alvis "Leonides 50" engine. A number of civil versions (Westland-Sikorsky S-51) are also in use.

12

No.	MAKER AND TYPE	Seats	Engine and Take-off Output	ROTOR(S)					WEIGHTS				PERFORMANCE					
				No.	No. of blades	Construction [1]	Diameter	Area	Cruising r.p.m.	Weight equipped	Flying weight	Rotor area loading	Power loading	Speed			Ceiling		Normal Range
														Max.	Cruising	Rate of Climb	Hovering	Oblique flight	
				—	—		ft.	sq.ft.	r.p.m	lbs.	lbs.	lbs./sq.ft.	lbs./h.p.	m.p.h.	m.p.h.	ft./min.	ft.	ft.	miles
1	Bell 47D-1 (H-13B; HTL-3)	3	Franklin 6V4 178 HP	1	2	tail rotor	35.2	975	333	1,380/1,580	2,200	2.3	12.4	92	85	800	—	11,000	200
2	Bell 48A (YH-12B)	5/8	Pratt & Whitney R-1340 600 HP	1	2	tail rotor	47.5	1,790	279	4,450	6,290	3.5	10.5	105+	90	900	—	15,000	500
3	Bell 54 (YH-15)	2	Continental or Franklin 275 HP	1	2	tail rotor	36.8	1,065	332	2,000	2,700	2.5	9.8	100+	—	—	—	—	200+
4	Hiller 360 (H-23A; HTE-1)	3	Franklin 6V4 178 HP	1	2	tail rotor	35.0	965	327	1,450	2,250	2.4	12.6	84	76	720	—	9,840	200
5	Piasecki PV-3 "Rescuer" (HRP-1)	10	P. & W. R-1340 600 HP	2	3	contrarotating tandem	41.0	2,650	—	5,000	6,900 [1]	2.6	11.5	105	85	800	4,500	12,000	300
6	Piasecki PV-14 "Retriever" (HUP-1)	5/7	Continental R-975 525 HP	2	3	contrarotating tandem overlapping	35.3	appr. 1,240	—	3,970	5,360 [2]	appr. 4.3	10.2	130	110	1,600+	8,000	16,500	400
7	Sikorsky S-51 (H-5 ; HO3S-1)	4/5	P. & W. R-985 450 HP	1	3	tail rotor	49.0	1,890	194	3,805	5,500	2.9	12.2	103	85	1,000	5,000	14,600	255
8	Sikorsky S-52-2 (YH-18 ; HO5S-1)	3/4	Franklin 6V6 245 HP	1	3	tail rotor	33.0	860	—	1,650	2,600	3.0	10.5	118	92	1,050	2,800	12,500	415
9	Sikorsky S-55 (H-19A ; HO4S-1)	12	P. & W. R-1340 600 HP	1	3	tail rotor	53.0	2,220	194	4,200	6,800	3.1	11.5	110	86	1,100	3,600	14,600	470
10	Kaman K-225 (HOK-1 ; HTK-1)	3	Lycoming O-435 225 HP	2	2	contrarotating side-by-side intermeshing	38.0	appr. 1,300	236	1,800	2,500	appr. 1.9	11.1	73	65	1,000	4,000	12,000	200
11	Bristol 171 Mk.3	4/5	Alvis "Leonides" LE 23 HM 550 HP	1	3	tail rotor	48.6	1,860	—	3,537	5,200	2.8	9.5	141	100	—	5,000+	19,000	330
12	Westland-Sikorsky "Dragonfly HR Mk.1"	4	Alvis "Leonides 50" 525 HP	1	3	tail rotor	48.0	1,820	—	4,305	5,870	3.2	11.2	103	85	—	6,900	14,000	230

[1] With overload 8,000 lbs. [2] With overload 5,600 lbs.

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Experimental Models

13

BAUMGARTL PB. 61 (BRAZIL)
This small helicopter built by Fabrica do Galeao (Rio de Janeiro) for the Brazilian Air Ministry carried out its first tests in August 1950. The PB. 61 is the first helicopter built in South America (designer Paul Baumgartl).

SZNYCER-GOTTLIEB S.G. VI-D (CANADA)
Our picture shows the second prototype of this three-seater, which was derived from the earlier S. G. VI model (begun in 1945) and is regarded as the basis for the production model. A military version has also been produced and tested. (Designers Bernard Sznycer and Selma Gottlieb).

15

PICKEN "HELICON" (CANADA)
145 h.p. helicopter built to try out a new type of rotor hub design. Tests were satisfactory and construction of an improved model is planned. This will have the same rotor arrangement but a more powerful engine. (Designer H. B. Picken.)

BRÉGUET "GYROPLANE BR. 111" (FRANCE)
Prototype for one pilot and four passengers derived from the earlier G 11 E (with 280 h.p. engine; our picture) by fitting a 455 h.p. engine (P&W "Wasp"). With co-axial three-bladed rotor, the "Gyroplane" has a fixed fin and a movable elevator unit.

17

CENTRE NC 2001 (FRANCE)
This five-seater built at the SNCA du Centre from designs by Dorand made its first flight in June 1949. The design is being further developed by one of the SNCA du Sud-Ouest's research offices.—Dorand is also working on the plan for a "crane helicopter" (NC 2420).

NORD 1700 "NORÉLIC" (FRANCE)
Two-seater, with tail propeller (slipstream in direction of flight) and vertical control surfaces (gyrodyne). Has been undergoing trials for a long time. A later version (Nord 1710) is said to be designed for artillery spotting. (Designer M. Bruel.)

19

SNCA-SO 1110 "ARIEL II" and SO 1120 (FRANCE)
Two-seater (picture) or three-seater (SO 1120) with jet propulsion, developed from the SO 1100 (first flight 1947). A turbo-compressor driven by a 190 h.p. engine (Mathis) or 275 h.p. gas turbine (Turboméca "Artouste") feeds air to burners at the blade tips, where fuel is injected.

SNCA-SE 3000 (FRANCE)
Six-seater with side-by-side contrarotating rotors and 1000 h.p. engine; first flight in October 1948 followed by extensive flight testing. Altogether three helicopters of this type were built.

21

SNCA-SE 3101 (FRANCE)
Single-seater model No. 1 of a series of small helicopters to serve primarily for testing the rotor arrangement. It has a lifting main rotor and two oblique anti-torque tail rotors and is powered by a 100 h.p. engine (Mathis).

SNCA-SE 3110 (FRANCE)
Two-seater with 203 h.p. Salmson NH engine and enclosed fuselage. Further development (SE 3120) to be used in agriculture, as ambulance helicopter, for reconnaissance and observation. The SE 3120 will have only one tail rotor.

23

CIERVA W. 11 "AIR HORSE" (GREAT BRITAIN)
The first prototype of this super-helicopter designed for 24 passengers, with a 1645 h. p. engine, was wrecked in an accident; a second is under construction. A twin-engined version (W. 11T) for 32 passengers or freight is being prepared (two Rolls-Royce "Merlin 502" engines of 2610 h.p. each, or gas turbines).

CIERVA W. 14 "SKEETER" (GT. BRITAIN)
Two-seater built in several versions: "Skeeter Mk. 1" with 110 h.p. Jameson F. F. 1 engine, "Skeeter Mk. 2" with 147 h.p. D. H. "Gypsy Major 10," "Skeeter Mk. 4" with 183 h.p. Blackburn-Cirrus "Bombardier." Our picture shows the "Skeeter Mk. 2," which made its first flight in October 1949.

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FAIREY "GYRODYNE" (GREAT BRITAIN)
Four-seater gyrodyne combines the principle of the autogyro with that of the helicopter. First flight in December 1947; speed record 124.3 m.p.h. in June 1948 (since exceeded by Sikorsky S-52 by 6 m.p.h.). First prototype was destroyed in an accident, second about to be flight tested.

BGM "LIBELLULA" (ITALY)
Two-seater developed by Bordoni, Giannini and Manzolini; first flight already completed. Co-axial rotors, drop-shaped fuselage, fixed vertical tail plane in three parts, with horizontal control surface. Four-seater version planned.

26

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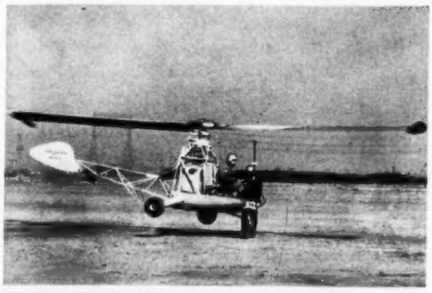

AMERICAN HELICOPTER XA-5 "TOP SERGEANT" (USA)
Experimental single-seater, jet-powered, so-called "pulse-jets" (first flight January 1949). The same firm also builds the engines. Further developments of the XA-5 are planned and the makers estimate they could put a production model on the market for $5,000.

28

DOMAN LZ-2A "PELICAN" (USA)
Two prototypes of the helicopter designed for crew of two and five passengers, whose novel rotor arrangement has already been tried out (in a Sikorsky R-6), are under construction. The earlier model was designated LZ-1A; a 11-seater LZ-4 is being developed for use in the Arctic.

18

29

HILLER "HORNET" (USA)
Originally designed for civilian use, this two-seater is now to be supplied to the USAF and US Navy. Its "inherently stable" two-bladed rotor is driven by Hiller ramjets of 30 lbs thrust each, weight 11 lbs. (1 h.p. starter motor; electric ignition; fuel feed through the hollow rotor blades).

30

KELLETT XH-10 (USA)
Twin-engined 12-seater designed for the USAF; underwent extensive tests, then was wrecked (sole prototype). Civilian version KH-2A (2 × 810 h.p.) for 12 to 16 passengers announced. — Plans for a jetpowered super-helicopter, XH-17, were handed over to Hugues Aircraft Co. in 1948.

20

31

McDONNELL XHJH-1 "WHIRLAWAY" (USA)
A Navy order for this twin-engined 12-seater, the first twin-engined helicopter in the world, was given to McDonnell as early as 1944; a prototype (so far the only one) flew in 1947. Flight testing which had been suspended for some considerable time, is to start again.

32

McDONNELL XH-20 "LITTLE HENRY" (USA)
Flying test bench to test the ramjet engines developed by McDonnell for rotor drive. Ordered by the USAF in 1946, first flight by prototype in May 1947. Test flights showed that flying qualities in auto-rotation needed improvement.

22

33

MARQUARDT M-14 "WHIRLAJET" (USA)
Marquardt, a branch of General Tire and Rubber Co., is particularly known for research work in connection with ramjets and pulse jets. The M-14 experimental single-seater was built to test jet-driven rotors and is fitted with pulse jets.

34

PENTECOST "HOPPI-COPTER 104" (USA)
Pentecost's (American) Hoppi-Copters Inc. was founded in 1945 and developed several versions of this small helicopter. Versions 102 and 104 were also tried out in Great Britain, where the British firm of Hoppi-Copters Ltd. (Marwyn Ltd.) is to build it under licence.

24

35

PIASECKI PV-15 (HX-16) "TRANSPORTER" (USA)
Twin-engined large helicopter for long-range rescue missions for the USAF, but also to be used by the US Army and Navy (picture of model). First flight probably 1952. Fuselage almost as long as the Douglas C-54 "Skymaster"; removable tanks can double useful load.

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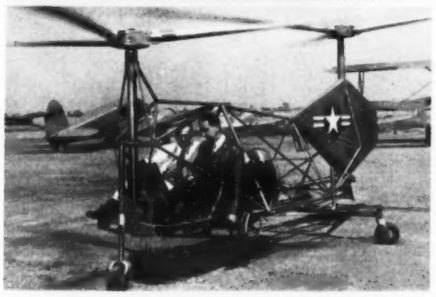

ROTOR-CRAFT XH-11 (USA)
Two-seater, undergoing trials until 1948, then was wrecked in an accident. Nothing is known about its further development, although the firm has recently worked out a multi-purpose helicopter, the "Heli-Jeep" for the USAF, which is also to be fitted with tandem rotors.

No.	MAKER AND TYPE	Seats	Engine and Take-off Output	ROTOR(S)						WEIGHTS				PERFORMANCE					
														Speed			Ceiling		
				No.	No. of blades	Construction	Diameter	Area	Cruising r.p.m.	Weight equipped	Flying weight	Rotor area loading	Power loading	Max.	Cruising	Rate of Climb	Hovering	Oblique flight	Normal Range
				—	—		ft.	sq.ft.	r.p.m.	lbs.	lbs.	lbs./sq.ft.	lbs./h.p.	m.p.h.	m.p.h.	ft./min.	ft.	ft.	miles
13	Baumgartl PB.61	1	Continental 65 HP	2	2	contrarotating co-axial	27.3	581	—	560	760	1.3	11.7	—	—	—	—	—	—
14	Sznycer-Gottlieb S.G.VI-D	3	Franklin 6A4 178 HP	1	4	tail rotor	34.0	908	279	1,700	2,375	2.6	13.3	90	80	860	—	—	120
15	H.B. Picken "Helicon"	—	De Havilland "Gipsy Mayor" 145 HP	1	3	tail rotor	—	—	—	—	—	—	—	—	—	—	—	—	—
16	Bréguet "Gyroplane" Br.111	5	P. & W. R-985 "Wasp Junior" 450 HP	2	3	contrarotating co-axial	31.5	780	—	3,250	4,630	5.9	10.3	133	108	—	5,250	15,000	290
17	Centre NC 2001	5	SNECMA-Renault 12 S 00 495 HP	2	2	contrarotating side-by-side intermeshing	45.3	appr. 1,940	240	—	5,500	appr. 2.9	appr. 11	155	137	—	6,560	16,400	370
18	Nord 1700 "Norélic"	2	Mathis G 7 158 HP	1	2	tail rotor in direction of flight	33.0	860	—	approx. 1,540	2,090	2.4	13.2	115	96	—	5,000	9,840	250
19	SO 1110 "Ariel II"	2	Mathis 8 G 40 187 HP	1	3	jet-powered rotor	35.3	990	260	1,630	2,380	2.4	—	102	84	1,060	4,000	8,530	53
20	SE 3000	6	Bramo Fafnir BMW 323 990 HP	2	3	contrarotating side-by-side	39.4	2,450	—	7,540	9,480	3.8	9.6	106	—	1,570	13,120	22,960	190
21	SE 3101	1	Mathis 4 G 20 100 HP	1	3	2 tail rotor	24.6	474	—	880	1,150	2.4	11.5	75	—	650	2,300	9,840	60
22	SE 3110	2	Salmson 9 NH 200 HP	1	3	2 tail rotor	39.4	1,225	—	1,480	2,090	1.7	10.5	110	80	885	4,590	14,760	185
23	Cierva W.11 "Air Horse"	2+24	Rolls-Royce "Merlin 24" 1620 HP	3	3	3 main rotor	47.0	5,200	—	12,140	17,500	3.4	10.8	150	116	1,210	11,000	25,000	330
24	Cierva W.14 "Skeeter 2"	2	De Havilland "Gipsy Major 10" 145 HP	1	3	tail rotor	32.0	810	—	1,200	1,800	2.2	12.2	95	77	1,030	7,200	8,250	190
25	Fairey "Gyrodyne"	4-5	Alvis "Leonides" 520 HP	1	3	main rotor and propeller	52.0	2,130	—	3,450	4,800	2.3	9.2	140	120	1,000+	—	18,000	250
26	BGM "Libellula"	2	CNA D4 75 HP	2	2	contrarotating co-axial	26.3	540	360	550	1,100	2.1	14.7	115	93	—	—	10,800	375
27	American Helicopter XA-5 "Top Sergeant"	2	2 AHCo. AJ-8.75 Pulsejets 2×95 lbs. Thrust	1	2	jet-powered rotor	33.0	850	—	900	1,400	1.6	—	75	55	—	—	—	200
28	Doman LZ-2A "Pelican"	7	Franklin 245 HP	1	4	tail rotor	45.0	1,590	200	1,800	3,200	2.0	13.0	85	75	1,135	3,280	14,000	225
29	Hiller "Hornet"	2	2 ramjets 2×31 lbs. Thrust	1	2	jet-powered rotor	—	—	—	356	—	—	—	85	70	—	—	—	50+
30	Kellett XH-10	12	2 Continental R-975 2×525 HP	2	3	contrarotating side-by-side intermeshing	65.0	3,700	—	8,256	11,000	3.0	10.5	120	90	1,650	6,000	18,000	350
31	McDonnell XHJH-1 "Whirlaway"	10/12	2 P. & W. R-985 "Wasp Junior" 2×450 HP	2	3	contrarotating side-by-side	50.0	—	—	8,000	11,000	—	12.2	110	90	1,300	—	—	350
32	McDonnell XH-20 "Little Henry"	1	2 McDonnell jets	1	2	jet-powered rotor	18.0	258	—	280	600+	2.3+	—	50+	—	—	—	—	—
33	Marquardt M-14 "Whirlajet"	2	2 Marquardt Pulsejets	1	2	jet-powered rotor	29.0	660	—	approx. 800	appr. 1,100	appr. 1.7	—	85	60	—	—	—	—
34	Pentecost "Hoppi-Copter 104"	1	40 HP	2	2	contrarotating co-axial	17.0	226	—	—	appr. 300	appr. 1.4	appr. 7.5	appr. 60	—	200	—	—	—
35	Piasecki PV-15 (XH-16) "Transporter"	—	2 engines	2	3	contrarotating tandem	—	—	—	—	—	—	—	—	—	—	—	—	—
36	Rotor-Craft XH-11	2	Continental 100 HP	2	3	contrarotating tandem	appr. 18.0	appr. 463	—	—	1,350	appr. 2.9	appr. 13.5	—	—	—	—	—	—

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Helicopters

Bigger and Better

Hughes Makes Helicopter News

Again the stage is being set for a "World's Largest" première by Howard Hughes, Texan millionaire industrialist, Californian aircraft producer, Hollywood movie maker, round-the-world record pilot. If all goes well the curtain may be raised before the end of this year to display the first free flight of the "world's largest" helicopter—the jet powered XH-17. Rehearsals, begun seven months earlier and halted by an accident, were resumed on January 23rd when the ungainly air monster was rolled on to a special test apron at Hughes Airport, in Culver City, California, for anchored whirl tests.

When flight controls, tail boom, tail rotor and horizontal stabilizer have been added, it will be ready to give substance to all the wishful conversation that has portrayed "flying crane" helicopters to lift stranded tanks across a river to give chase to an enemy who burned and blasted his bridges as he fled.

That will be the *raison d'être* of the show—if it comes off as laboriously planned; the justification for spending goodness-knows-how-many-millions of dollars on the project by U.S. Air Force, which appears in the cast as the financial angel of the spectacle.

Rotary wing engineers who figure they could demonstrate with a slide rule and a few sheets of equations the performance probabilities of such a machine, and the economically-minded who still shudder at the twenty-odd millions poured into Hughes' "world's largest" flying boat, which has half-flown once, are maintaining prudent silence as the XH-17 approaches completion.

Both of those factions have discovered that the superlative-loving American public really doesn't give a damn for their opinions. Popular imagination has been captured and completely captivated by the fact that, while a lot of people have talked about big helicopters, Mr. Hughes has quietly done something about it.

It was one thing for a leading commercial helicopter builder to proclaim, a couple of years back, "We could build a helicopter big enough to lift our factory building right into the air!" Other helicopter manufacturers have pictured giant jet 'copters leapfrogging rivers and roadless terrain with tanks, field guns and trucks slung beneath their roaring rotors.

In June, 1948, General Electric advertised the then only relatively secret details of the giant helicopter. Picture shows men working on the jet orifices in the tip of one of the mammoth rotor blades.

The American public has a classic response to such predictions: "Everyone talks about the weather, but no one does anything about it."

The XH-17 is cloaked in secrecy as to its detailed dimensions, the weight it is expected to lift, the distance is should be able to fly, the possibility that it might, some day, go into production. All that USAF will say about the monster is this:

"The helicopter is powered by two modified General Electric turbojets supplying air through ducts leading to the rotor shaft and out to the tips of the rotor blades. The XH-17 is designed for short-range moving of military equipment such as trucks, tanks, bridge sections, etc., over all kinds of terrain. In operation it will straddle its cargo in a manner similar to that of a lumber lift, picking up heavy loads by attachments to landing gear and body." Los Angeles newspaper photo editors, using as a "yardstick" the mechanics appearing in the Air Force-approved photo, have estimated that the XH-17 has a rotor span of 120 feet.

This secrecy was as pronounced as it was absurd last summer when the XH-17 was rolled out into clear view and a wandering news photographer clicked his shutter at what his eyes saw. His "grab shot" was rushed by air mail and wire photo to eager newspapers throughout the nation.

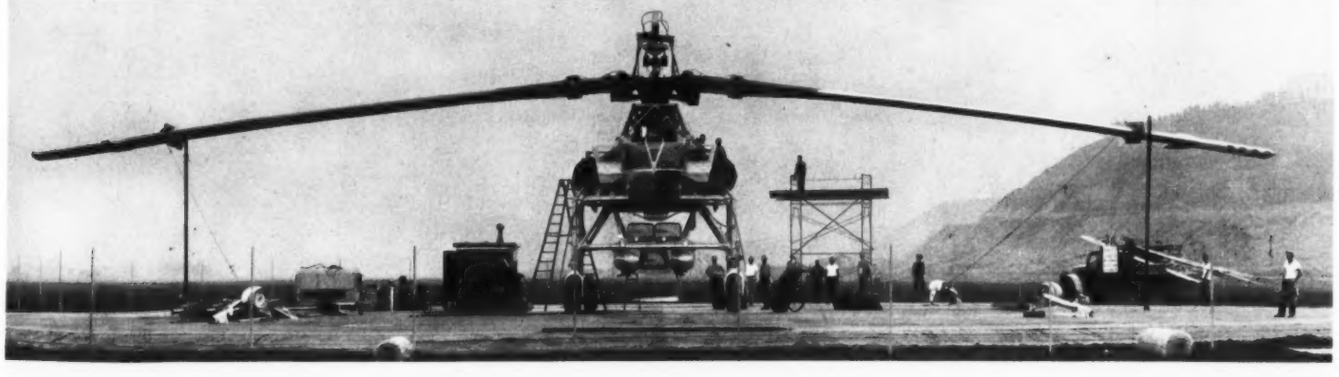
A resultant F.B.I. investigation was immediate and nation-wide. No heads rolled, but the secrecy ruckus and government probe was as effective in whetting curiosity over the contraption as if it had been engineered by a top-flight Hollywood press agent. It left the American press figuratively drooling for more information about the big helicopter of Mr. Hughes, whose name is "Mr. News" any time it hits an editor's desk.

Curiously enough, the XH-17 didn't even start out as the "Hughes Helicopter." It was the conception of two eastern firms, Kellett Aircraft Corp., of North Wales, Pennsylvania, and General Electric Corp., of Schenectady, N.Y. Some time prior to 1948 Kellett and G.E. sold the Air Force on the idea of underwriting the machine as an experimental project, General Electric to test out the application of jet power to the biggest rotors ever built.

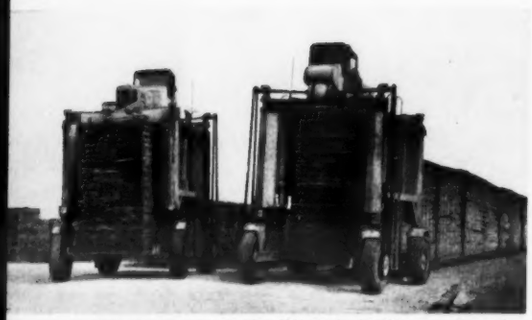
General Electric in June, 1948, ran full-page ads picturing mechanics adjusting the jet exhausts on one of the big blades and telling that it was "a project for the US Air Force that has been under way for more than a year at the G.E. Flight Test Center in Schenectady, in co-operation with our Aircraft Gas Turbine Division in Lynn, Mass."

Kellett Corp., did not publicize its own major part in executing the overall design of the machine. The publicity that Kellett was receiving at the time was that the firm was in dire straits financially and would have to sell its helicopter projects, including the big one, to satisfy its creditors.

Hughes was not the only one who hoped to reap the final glory of claiming the world's largest helicopter. Fairchild Airplane & Engine Corp. of Hagerstown, Maryland, made a fast bid of $185,000 for the Kellett helicopter properties. Hughes, dealing within the Kellett company with influential



The Hughes XH-17 giant helicopter. Rotor span is estimated between 120 and 130 ft. The size of the machine can be judged by the men standing on and beside it. Note jet exhaust nozzles at extreme right blade tip, water tanks between legs to hold ballast during tie-down tests. The four-wheeled structure intended to undertake the 'copter's lifting strangely resembles the giant lumber carriers built by the Ross Carrier Company, of Benton Harbour, Mich, USA.



The lower part of the XH-17 looks like an adaptation of one of the Ross lumber carriers, the biggest of which has a 40,000-lbs. capacity. Sports car enthusiasts like to catch an unloaded carrier rumbling down a highway and scoot between its legs, to the consternation of the innocent carrier driver perched high above.—The XH-17 is presumed to have a lifting capacity of 24,700 lbs.

major stockholders, won the deal for a reported $150,000.

It was in the excitement of the mad scramble for a choice engineering project that the first specification details of the big machine came to light: it would be powered by two TG-180 turbojets driving ram air through blade ducts to "four burners" (in principle resembling afterburners) at each rotor tip. Each all-steel blade would be 65 feet long, presumably giving the helicopter a disc diameter of 130 feet. The machine was designed to carry 24,700 pounds a distance of 65 miles.

When the machine next broke into public print, nearly two years later, it was in final stages of assembly in Hughes' Culver City factory, and to all appearances was an original Hughes project. The military designation had been changed from "XR-17" ("R" for Rotor) to "XH-17" ("H" for Helicopter).

It is doubtful that anyone could have taken up the project and bulled it through to completion as successfully as this Texan who dotes on "bigness" in everything he touches. Assuredly Kellett was in no position to finish the monstrous thing it had started.

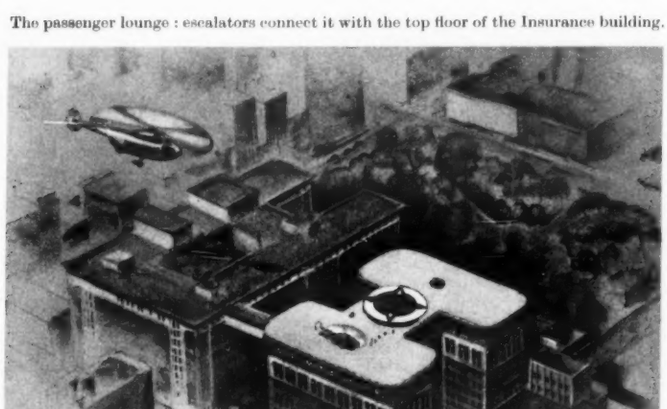
What many Southern Californians would like to see, when the XH-17 dons its flight controls, would be a good, dramatic lifting contest with what it most resembles—a highway lumber carrier, that long-legged vehicle rumbling along American roads astraddle imposing loads of almost any commodity which needs lifting and moving over short distances.

S. B.

Down-Town Heliport

Los Angeles "Heliport": A raised landing deck would be built on the roof of the building of the Pacific Mutual Life Insurance Co.

The passenger lounge : escalators connect it with the top floor of the Insurance building.



Modern airports are situated twenty minutes to an hour from the centre of a city, depending upon the latter's size. Motorcars capable of travelling 100 miles per hour on the open road crawl along at about four miles per hour through city traffic. Large business centres in every part of the world attract thousands of workers from outlying towns who every morning and every evening waste from thirty minutes to one hour-and-a-half travelling to and from their places of employment—and on each trip the poor creatures are nearly crushed to death in ancient subway coaches, evil-smelling commuter trains and bone-shaking omnibuses.

Suitable commuter helicopters—so far none have reached the operational stage, for they would require at least two engines to fly over densely populated areas with complete safety—could do much to relieve this traffic congestion. Passengers could fly from the centre of the big cities to their homes or to the airport in a matter of minutes. And indeed a Californian helicopter operator has already worked out plans to connect downtown Los Angeles with 23 outlying communities in flying times ranging from 5 to 24 minutes. Los Angeles to Long Beach, for instance, would take 12 minutes by helicopter, instead of a full hour on the so-called Pacific Electric Railroad, a garishly red, most horribly uncomfortable means of locomotion. New York helicopter operators, too, have established tentative schedules which would serve about forty points in New York State, Connecticut and New Jersey, including the city's three major airports.

The inauguration of such services depends not only on the development of reliable passenger helicopters, but also on the availability of suitable landing sites in the centre of large cities. In the outlying small towns it will nearly always be possible to find an unoccupied area for the purpose. The problem is more difficult in congested business areas, which offer only one solution: utilization of the roof area of large buildings.

In Los Angeles the company which operated experimental mail services until the end of last year, Los Angeles Airways, used the roof of the Los Angeles Central Post Office as its down-town terminal. This was a purely temporary arrangement, and some weeks ago the establishment of a more permanent facility was proposed. The Pacific Mutual Life Insurance Company announced that it would be willing to build a complete « heliport » atop its twelve-storey building in the centre of the Los Angeles business district. The ground floor of the building houses a cluster of down-town ticket offices of major and « independent » airlines, and the site adjoins the Biltmore Hotel, one of Los Angeles' largest hostelries. Plans provide for a raised-platform landing deck surmounting the present roof of the insurance company's office. Centrally in the landing area would be a passenger lounge served by escalators from the top floor of the building. Cost of the project is estimated at $250,000

Much cheaper would be a plan drafted by the Port of New York Authority which would modify the roof of the General Post Office in the centre of Manhattan for only $80,900. For the use of giant passenger helicopters, carrying up to 40 passengers, however, the Authority would make available the roof of its new bus terminal a few blocks away, which could be strengthened and equipped as a "heliport" for about $500,000.

How to Fly a Helicopter

BY NILS OLOF SEFELDT, VÄSTERAS, SWEDEN

Here in Sweden is a man who has attempted more in aviation than most Swedes. In 35 years he has flown a countless number of aircraft types; he has flown in all kinds of weather not only in our own country but also on the Atlantic—as long ago as 1926. But he had not flown the latest in aviation—the helicopter. I invited the old pioneer, Captain Albin Ahrenberg, to a little demonstration flight in connection with the first showing of the Bell helicopter in Sweden in the early part of 1947. After the flight his voice trembled with enthusiasm, his eyes beamed with delight as in younger days, and he said: "I have had lots of fun in my day, but this was really the best."

He was right. To fly in a helicopter is an experience that is unequalled in aviation. Not only is it great fun to fly a helicopter, but there is also a vast variety of tasks which can be performed solely by the helicopter. There is, no doubt, a great deal of work that hitherto has been left undone due to the lack of means to accomplish it. Since the helicopter has come into practical use it has been employed for many strange assignments. For instance, a Swedish factory wanted a hoist put atop a 300-ft. smoke stack. This was easily performed with the aid of the helicopter. A Norwegian shipowner, with a fleet of whalers, plans to use helicopters for spotting whales. A swimming club used the helicopter as a spring board at a swimming and diving exhibition in Hälsingborg. And a man of imagination has dreamed up the idea of solving the "secret of the elephants" by means of the helicopter. He suggests that an elephant should be tracked, wounded and then followed to its elusive burial ground. He believes this would result in a fortune in ivory for the finder.

Tasks like these could hardly be entrusted to the novice helicopter pilot. It requires considerable training to get the precision in flying that is necessary for work of this type and for more useful tasks like dusting and spraying, powerline patrol, rescue flying in bad terrain, roof-top landings and take-offs, flying in confined spaces, etc.

The author, Nils Olof Sefeldt (in the cabin), talking to David G. Forman, Manager of the Bell Aircraft Corp. Helicopter Division.

Even an experienced pilot on conventional aircraft takes approximately 20 hours to qualify for a private helicopter pilot's license. Veteran aeroplane pilots, strangely enough, need considerable time to unlearn much of what they have accumulated during years of flying. Of value to the pupil with previous flying training principally is his practice of thinking while in the air and his familiarity with engines and instruments. Otherwise I think that it is no harder to train a man with no flying experience at all than an expert pilot.

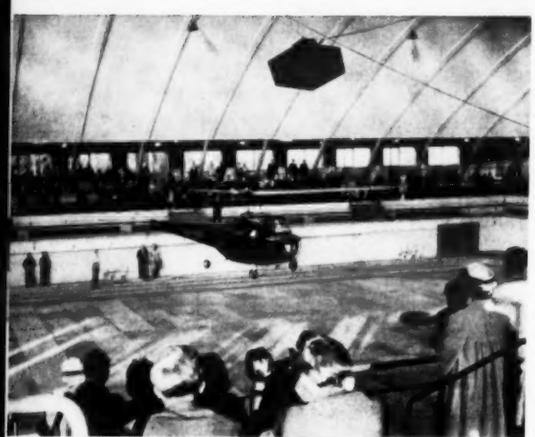
Interior of the Bell 47 B two-seater helicopter. *Foot pedals* (tail rotor control = rudder) are just visible at extreme left. *Stick* (cyclic-pitch control) is provided for each of the two seats. *Collective pitch lever* with motor-cycle-type *throttle* at left of each seat.

What, then, are the difficulties of helicopter flying, and how is the helicopter flown? This article will attempt to convey an outline of the problems involved to non-helicopter pilots. The helicopter referred to is the Bell Model 47, a two-seater with a single two-bladed main rotor and an anti-torque rotor at the tail. The power output of the engine is 178 h.p.

Let us suppose that the engine has been started and warmed up and that we are going to make a flight in order to observe the function of the different controls. The Bell 47 is operated by three principal controls:

(1) *Control column (stick):* This is situated in the position of the stick in conventional aircraft and controls the cyclic pitch of the helicopter, which governs the latter's direction of flight within a full 360 degrees. The stick tilts the rotor by causing each main rotor blade to assume the highest angle of pitch at the desired point in the rotational cycle and the lowest pitch at a point diametrically across the rotor disc. As a result, the helicopter can fly forwards, backwards or sideways.

(2) *Foot pedals:* In the Bell 47 the rotor turns anti-clockwise, from right to left as seen from the pilots' seat, and the resulting torque would cause the fuselage tail to turn to the left (and the nose to the right). To counteract this, the vertical anti-torque rotor is fitted on the starboard side of the helicopter tail. By varying the pitch angle of the vertical rotor blades, and hence the thrust they exert about the vertical axis of the aircraft, the rotor also provides complete



Nils O. Sefeldt at the controls of the Bell 47 B during the third indoor flight in the world in the "Mässhall," Gothenburg in 1947. The first two indoor flights were made before World War II by Hanna Reitsch, noted German pilot, with a Focke-Achgelis helicopter in the "Deutschlandhalle" in Berlin.

directional control, in addition to the mere anti-torque effect. The pitch of the vertical rotor blades is increased or decreased by depressing one or the other of the foot pedals —which in conventional aircraft fill a similar function by operating the rudder. But, since the main rotor torque will vary with the power output of the engine, the vertical rotor blade pitch has to be adjusted to varying flight conditions by means of the pedals.

(3) *Collective rotor pitch lever and throttle:* The main rotor pitch control lever is situated nearly horizontally to the left of the pilot's seat. When this lever is moved upwards, the pitch of both blades of the Bell 47 is increased simultaneously and equally, the lift augments and the helicopter rises. Pushing the lever down conversely decreases pitch and lift. The hand grip of the lever incorporates the motorcycle-type throttle: when the grip is twisted to the left, engine output is increased; turning it to the right decreases power. For climbing, therefore, the lever is pulled up and its grip simultaneously twisted to the left. However, by a system of cams, collective-pitch and throttle controls have been made synchronous once the throttle is adjusted to provide the desired rotor speed.

We now increase the engine r.p.m. to a value where the centrifugal clutch engages the engine to the rotor. The rotor slowly turns above our heads. We increase the engine speed by turning the motorcycle-type throttle on the main rotor collective pitch lever to the left. The speed of the engine should be 3000 r.p.m., no more and no less, and should be the same under all flying and taxiing conditions. We hold the cyclic pitch control stick in the neutral position while we slowly pull up the main rotor collective pitch lever. If we don't increase the throttle opening at the same time the r.p.m. will decrease because of the increased load on the engine resulting from the rotor's lifting efforts. We therefore open the throttle more and more and slowly we rise from the ground. If the helicopter has any tendency to turn either to the right or left we correct this by increasing the pressure a little on the opposite "rudder" (tail rotor) pedal. If the helicopter tends to drift horizontally in any direction—forwards, rearwards or sideways—we counteract this tendency by a slight pressure on the control (cyclic pitch control) stick in the opposite direction. Remaining stationary in the air is about the same as "treading water" and is called "hovering." If we now lift the main rotor collective pitch lever we climb as in a fast elevator. If we lower the same lever we sink in the same way. This ascent and descent can be stopped anywhere and at any time. The reaction is instantaneous.

From the hovering position it is simple to demonstrate the use of the cyclic pitch control. To fly forwards we push the control stick slightly forwards. Correspondingly, to fly backwards or sideways, we push the stick a little bit in the desired direction. If we fly forwards and want to stop, we do this simply by pulling the stick a little backwards. Holding the stick in this position will cause the helicopter to start flying backwards. The speed depends solely on how far we push the stick.

In the hovering position we can also demonstrate the effect of the pedals. If we increase the pressure slightly on the right pedal we will turn to the right over a fixed point on the ground. If we increase the pressure on the left pedal we will turn left. The speed on the turn depends on how much the pedals are moved.

Take-off as well as landing is done in two stages. The first stage of the take-off consists of the vertical climb from the ground to hovering position. The second phase we start from this position by increasing the pressure on the control stick in the direction we want to fly, usually forward, and when we start inching ahead we increase the collective pitch of the main rotor blades in order to get increased lift and increased speed. As we now fly forwards about 3 feet above the ground we suddenly start to climb. As the forward speed increases, the efficiency of the rotor system also increases and we automatically get increased lift. When a rotor system moves through the air its total lift becomes greater than if the rotor were stationary in the air. This so-called "translational lift" is a function of the airspeed. From 0 to 15 m.p.h. the translational lift is rather small but increases rapidly from 20 m.p.h. on up. With a certain setting of power and pitch the helicopter will start to climb when it changes from hovering to horizontal flight in any direction. In order to change over to level flight the collective pitch of the rotor blades and the power of the engine must thus be reduced. Or, to explain it in another way, if we hover in still air and a wind gust suddenly hits the helicopter it will immediately climb. Because of this fact it is possible to start a helicopter even at great altitude or with such a great load that vertical take-off would be impossible. The temperature of the air also affects the take-off and hovering characteristics of the helicopter, so that on very hot days it may not be possible to make a vertical take-off or to hover a fully loaded helicopter.

Under circumstances like these we can still effect a take-off by the use of the translational lift property of the rotor. A running take-off is the answer. If the pilot finds that he cannot hover at over one foot with full throttle he should land and use the following take-off method, providing the ground is fairly level and makes such a take-off possible. The r.p.m. and manifold pressure should be set at such values that the helicopter will rest lightly on the wheels. Forward acceleration should be started by a slight forward movement of the control stick. When the speed reaches about 20 m.p.h. the pilot should ease back on the stick and lift the collective pitch lever to get highest possible power. This will lift the helicopter from the ground and forward acceleration and climb can be continued. The required rolling distance for such a take-off is only from 15 to 30 feet.

Best speed for climb is about 45 m.p.h. so we keep increasing the pressure on the control stick till we reach this speed. If the climb is not steep enough we only have

Mail delivery by helicopter is carried out by the Swedish General Post Office every winter and spring between the capital and the isolated islands of the Stockholm archipelago. Picture shows mail being loaded into the special containers fitted to a Bell 47 D utility helicopter. The pilot's Homburg hat looks appropriate . . .

to increase the pitch a little by lifting the collective pitch lever.

To level off we lower the collective pitch control lever somewhat, keep the airspeed at 45 m.p.h. and watch the altimeter. If the helicopter is equipped with a rate of climb indicator it is simpler to use this instrument. But we don't want to fly at only 45 m.p.h., so in order to increase our speed we move the control stick further forwards, but if at the same time we don't come up a little on the collective pitch control we will lose altitude. This is rather difficult—the right coordination between cyclic pitch and collective pitch.

We might now fly at 600 feet at a speed of 60 m.p.h. The fuselage of the helicopter changes its attitude with the speed. At high speed it flies with tail up and nose down, while at low speed it flies in a more level position. By watching the inclination of the fuselage it is therefore quite simple to keep the speed constant. Because the response of the helicopter to the movement of the control stick is not immediate, beginners sometimes feel slightly disturbed, although the delay in reaction is only a fraction of a second. If we move the stick slightly forward it will take a moment before the nose comes down and the speed builds up. Suppose we now fly at 80 m.p.h.; we maintain the position of the helicopter and control the speed by glancing at the airspeed indicator now and then.

Let us now see how a landing is performed. Normal procedure is to approach the point where you want to touch down on a flight path at an angle of about 30 degrees to the ground. The landing, as the take-off, is done in two stages; first, we land on the "ground cushion," i.e., before we touch down the helicopter should hover about 3 feet above the landing point. The second stage is the actual landing after a vertical descent from hovering position. It is also suitable and easier to land straight into wind.

At the beginning of the approach the airspeed should be about 40 m.p.h. Since we probably are flying at a speed of about 80 m.p.h. we have to reduce the speed by moving the control stick slightly backwards. This will raise the nose. The speed will drop—from 80 to 70 and to 65 m.p.h. We now ease the stick gently forwards and attempt to maintain 40 m.p.h. Since we want to descend we also have to lower the collective pitch lever and reduce power so the engine doesn't overspeed. We keep the fuselage in a constant position and observe the angle at which we approach the ground. If we sink too steeply we have to increase the collective pitch a degree. If we seem to overshoot we have to reduce the collective pitch. It is rather simple to control the approach angle. We should keep this angle constant until we are quite close to the place we have chosen for our landing.

Dusting of oak woods on Visingsö island, in lake Vättern, Sweden.

At about 100 feet we reduce the speed gradually so that we will have no forward speed at all when we are right above our landing spot. At the same time we very gently and gradually increase the collective pitch to produce a "braking" effect. When we are down to about 3 feet the helicopter should have come to a stop. Here we hover a moment. The only thing we now have to do to complete the landing is to lower the collective pitch lever slowly. When the wheels touch the ground we firmly push the collective pitch lever all the way down and reduce the power to make certain that we remain on the ground. We also put the control stick forward a bit at the same time to keep the main rotor away from the tail boom in case of pitching movements incurred over rough ground. One of the deep-seated reactions that airplane pilots have to overcome is the urge to pull back on the control stick when they get near the ground. This leads to a backward landing which is neither smooth nor safe.

A patient from an island in the Stockholm archipelago is safely delivered to a hospital in Stockholm.

But what would happen if the engine should stall? Suppose we are flying at 500 feet and slowly close the throttle. We have to be careful not to close the throttle too rapidly since the engine has no flywheel—or propeller acting as a flywheel—as on conventional aircraft. Therefore, these manœuvres should never be attempted over ground that is unsuitable for a landing. The rotor continues to rotate and acts exactly the same way as the rotor of an autogiro. This is called autorotation. To maintain the speed of the rotor we quickly push down the collective pitch lever and move the control stick forwards. When doing this we get a relatively steep glide path and if we move the control stick too far forwards the rotor will easily overspeed. Air speed should be about 45 m.p.h. We have complete control of the helicopter even with a dead engine. When we come close to the ground we only have to flare out by pulling slightly back on the control stick and gradually lift the collective pitch lever so we don't "pancake." The flare is executed in such a way that the helicopter will have a horizontal position at a height of about 3 feet. When there is no more forward speed the helicopter gently touches down.

This touch-down can also be done with some forward speed, when the helicopter will roll maybe 30 feet. In an emergency an absolutely vertical descent can be made. In this case, however, the speed of descent will be greater, but not great enough to endanger the lives of the passengers in any way. The necessity of having a certain amount of airspeed for autorotational landings is then quite obvious.

A general rule in case of engine failure is to put the collective pitch all the way down safely without hitting the ground and start coming up on it soon enough to break the descent. In case of failure while hovering there is one particular thing to consider. Since we are using a lot of left rudder when hovering the sudden lack of torque will turn the helicopter nose to the left—up to 90 degrees—depending on your original height above the ground and your reaction time with right rudder.

Besides engine failure there is finally one other thing to consider when hovering. Hovering at altitude should not be attempted during hot summer days since it is rarely possible to hold altitude at zero airspeed beyond ground effect. If settling starts and the rate of descent reaches 300-400 feet per minute, the pilot will experience a rather unpleasant settling with power which results in a partial loss of cyclic and directional control.

Preparing Commercial Helicopter Services

BY N.E. ROWE, C.B.E., D.I.C., B.SC., A.C.G.I., F.R.AE.S., WHIT.EX. CONTROLLER OF RESEARCH AND SPECIAL DEVELOPMENTS, BRITISH EUROPEAN AIRWAYS

It is now common knowledge that in the helicopter we have a new vehicle of transport offering all the advantages of movement in three dimensions. Given suitable types of aircraft, the helicopter will make possible point-to-point transit using small sites placed at the centre of cities. The stage distance compatible with efficient operation is between, say, 30 and 250 miles (although these limits are quite flexible) and one can foresee in the near future operating speeds which will permit a block speed of 100 miles per hour. The disposition of population in Western European nations, the community of interest between great cities separated by small distances and the steady pressure for improved communications, all go to indicate that this new vehicle of transport has the greatest potentialities in densely populated areas. In no other way does it seem to be possible to bring the benefits of air transport directly to very many great towns and cities.

If this new vehicle is to be successful, it must clearly show a marked advantage over the existing means of transport in time saved and convenience of the transit; the standards of speed, regularity and punctuality must be as good as those existing and the fare must not show too wide a disparity. These are difficult targets, but, in the opinion of the writer, they are within our power to accomplish over the next decade. Meanwhile, it will be necessary to determine numerous operational problems by practical experience as soon as possible.

Preparation

In 1946 British European Airways initiated a programme designed to provide this experience. It was fortunate for the Corporation that two types of helicopter, the Sikorsky S-51 and the Bell 47B both reached the stage of obtaining a Certificate of Airworthiness at about the same time that year, since it was possible to use these to form an Experimental Unit for the study of the operational problems. The Unit's fleet was composed of three S-51 and two Bell 47B aircraft. The S-51 is an aircraft weighing 5,300 lbs. maximum and capable of carrying three passengers for stage distances of about 150 miles; the Bell is a two place aircraft weighing about 2,150 lbs., capable of carrying two people a still-air distance of about 200 miles. We found both machines to possess high standards of mechanical reliability, but the nature of the tasks to be undertaken entailed the use of the larger aircraft almost entirely.

About the time that we were forming our Unit, Westland Aircraft Ltd., Yeovil, Somerset, obtained the licence to manufacture the S-51 aircraft in Great Britain. Hence, the BEA Helicopter Experimental Unit formed at Yeovil in July, 1947, where a hangar on the Westland airfield was prepared for their accommodation. The necessary complement of four pilots, five engineers, six other personnel and the aircraft fleet were assembled by December of that year. Wing Commander R.A.C. Brie was the Official-in-Charge. Full financial support for the operations of the Unit has been given by the Ministry of Civil Aviation to cover the balance between operating expenses and the revenues earned on various operations carried out by the Unit. In order to keep all interested parties informed of what we were doing and to give an opportunity for them to criticise and suggest, a Consultative Committee was formed by BEA, comprising representatives of the Ministry of Civil Aviation, Ministry of Supply, General Post Office, Air Ministry, Admiralty and Ministry of Town and Country Planning, and this has continued to meet periodically over the whole period.

The main operations which have been undertaken by the Unit since its formation are the following:

27th January — 7th March, 1948: Dummy mail carrying operation in Dorset.

1st June—25th September, 1948: Real mail operation in East Anglia.

23rd May—16th June, 1949: Croesor Dam operation, North Wales (charter).

17th October, 1949—15th April, 1950: Night mail operation, Peterborough-Norwich.

1st June, 1950, to present time: Welsh passenger service.

In addition, certain subsidiary operations were carried out, notably a good deal of training and much research and development, particularly on the problems of blind and night flying.

The activity with the General Post Office was initiated by discussion with them as early as December, 1946. They were interested not only in running experimental operations, but they also put forward very clearly *the need for carrying mail by night*—the usual time for mail transport—so that we were very early in our existence given the target of a practical night and blind operation.

Dummy Mail Operation

The purpose of the dummy mail operation in Dorset was to test the practicability of a helicopter mail service from the aspects of regularity and time-keeping to a close schedule. There was also the very practical point of use of postmen in this novel development, and it was clearly necessary to have a technique fully worked out before a practical mail carrying experiment was run.

A Sikorsky S-51 helicopter of British European Airways carrying three passengers arrives at Speke Airport, Liverpool, from Cardiff. The Liverpool—Cardiff service is the world's first passenger helicopter service.

The route served was Yeovil - Lyme Regis - Bridgeport - Weymouth - Dorchester - Wareham - Poole - Wimborne - Blandford - Gillingham - Sherborne - Yeovil. The schedule gave an average route speed of 60 m.p.h., that is, 115 miles of the route were covered in 115 minutes, which includes ten intermediate stops. The dummy mails were stowed on the floor of the passenger compartment, and initially means of securing them were provided, but it proved unnecessary to use this as it was found that the load did not shift, even in the most bumpy weather.

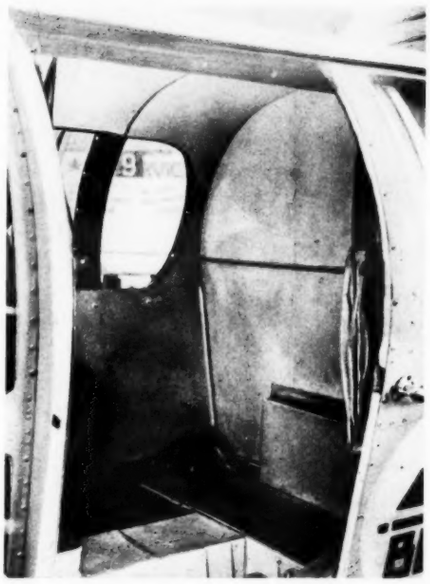
In this operation the landing areas were chosen to be as near to the Post Office as possible and accessible from the normal road services. In many cases pasture land or common was used, and in each case the point for the helicopter landing was marked by a chalk patch of about one yard diameter. The pilot alighted with the nose of the aircraft over this patch, and the postman was stationed about 30 paces up-wind, awaiting the aircraft which landed into wind. After a period of early trial when the rotors were stopped whilst the loading and unloading of mail was carried out, it was agreed that they could be kept rotating provided that the postman kept well clear of the tail rotor. When the transfer of load had taken place and the pilot had marked the change of load on his load sheet, the postman backed away past the nose of the aircraft and when he was clear the pilot took off. Time taken for the whole process at each stop was about one minute.

Over the trial period of one month (27th January—28th February), the regularity obtained was 94.8% of completed runs or 96% of scheduled calls. Of a total of 570 calls scheduled, six were not made as a result of a precautionary landing en route due to a defect in the fuel system (now rectified) and 17 calls were missed due to weather. Punctuality was in general satisfactory and within the five minutes early or late standard acceptable to the General Post Office. The weather during the period was particularly severe in terms of wind and low visibility, and winds of mean strength of 30 m.p.h. and gusting up to 60 m.p.h. were encountered on some occasions. Flights were made in heavy rain with the visibility as low as 500 yards. These conditions confirmed the excellent bad-weather capability of the helicopter.

Apart from the development of operating techniques with the Post Office, the method of carrying and stowing mails and the development of load sheets, the Dorset operation was of great value in tuning-up the Unit in all its aspects and in proving that practical operations were feasible under quite severe conditions with a high degree of effectiveness.

Real Mail Operation

Arrangements were now made with the G.P.O. to carry out an operation with real mail. Its object was chiefly to obtain information on the cost of helicopter services. The area selected was in East Anglia, based on a postal distribution centre at Peterborough. In this area the normal surface communications are poor, and considerable



For the carriage of mail the rear compartment of the S-51 was modified, the seats being removed and a ply semi-bulkhead was built between the rear compartment and the pilot to prevent the mail moving about.

expedition in mail times to and from other parts of the country could be obtained. Mails arriving at Peterborough too late to secure distribution in the majority of towns in Norfolk on the same day by normal surface means were loaded into the helicopter at Peterborough shortly before 10.00 hours and off-loaded at nine points over a route distance of 170 miles, in time to connect with the last delivery in every town visited. In the evening, mails were collected from five points over a route of 102 miles in length and off-loaded at Peterborough at about 19.30 hours for connection with main line trains.

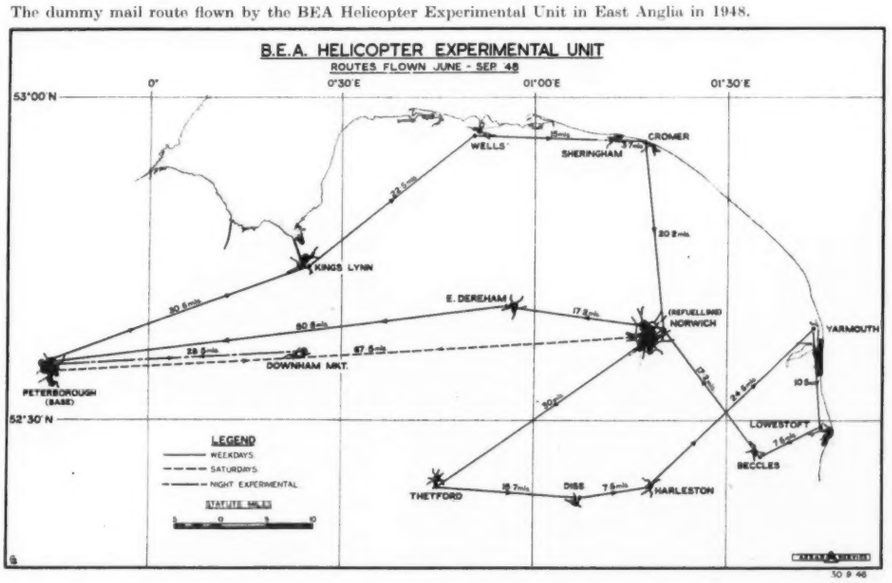
The schedule route speed, that is, route distance divided by time between termini, was 58.6 m.p.h. in the easterly direction and 53.2 m.p.h. in the westerly direction, the difference reflecting the stronger westerly winds expected during the period of operation. Both speeds included a nine minute refuelling stop at Norwich. These schedule speeds were based on punctuality on all except 1% of occasions, going east and on all except 5% of occasions coming west. The actual cruising speed used was about 85 m.p.h. The same technique developed in Dorset was used, ordinary fields were selected for the alighting points, sizes varying between two acres and twelve acres and mostly within a mile of the Post Office.

The Unit flew to Peterborough from Yeovil in formation on the 28th April, 1948. At Peterborough an old hangar was available and some adjacent buildings for offices. Familiarisation flying on the postal route commenced on the 10th May, a dummy mail rehearsal during the week from 24th—29th May, and on the 1et June a live mail operation started and continued until the 25th September.

The results, judged on the basis of trips entirely completed in time to connect with other postal services, were 95 % of the scheduled trips. By calls, 98.4 % of the scheduled calls were made. These very good results were achieved despite weather being worse than that normal for the time of the year. Flights were successfully completed on five occasions when the visibility was down to 400-500 yards. On one-third of the flights, visibility was 1,000 yards or less. These, of course, are below the standards laid down for I.F.R. conditions in fixed wing practice and bring out very strongly the ability of the helicopter to fly visually under very poor conditions of visibility. The amount of mail carried totalled 30,046 lbs.

Again, the maintenance record was extremely good and on no occasion was a scheduled run cancelled or delayed as a result of mechanical failure. Two aircraft were used on the mail run, the planned programme of flying and maintenance was adhered to

The dummy mail route flown by the BEA Helicopter Experimental Unit in East Anglia in 1948.



A BEA S-51 helicopter about to land to pick up mail. A GPO postman with his van is ready to load his mail bags.

and it was never necessary to draw on the reserve aircraft.

Very careful cost records were kept of this operation for purposes of our contract with the General Post Office and also for our own information in relation to future operations and the factors of cost which were of importance. The average cost per flying hour worked out at £28.4*s.* giving an average cost per route mile of 8*s.*6*d.* and 25*s.* per capacity ton mile. These costs are extremely high, of course, and reflect the basic poor economy of such a small aircraft. It must also be remembered that they are based on an annual utilisation of only 567 hours and a comparatively short period of amortisation, so that the fixed annual costs amounted to over 50% of the totals. What was most encouraging was the good engineering and maintenance costs relative to the others.

Blind and Night Flying Experiment

The need to develop a technique and equipment for night and blind flying had been on the programme from the outset and some early night flying had been commenced in Yeovil. Earlier work had been done, notably at the Ministry of Supply Test Establishment and under contract with the Ministry of Supply by Messrs. Fairey, but the total blind flying at that time was still very small. For the purposes of our experimental work, we converted the passengers' compartment in one of our S-51 aircraft into a blind flying training cabin. This was done by blacking out the whole of the interior by use of black curtains, installing dual control and a full set of blind flying instruments as shown in Figure 3. The only instrument specially modified was the artificial horizon, which had a variable horizontal datum. Flight trials with this arrangement were commenced on the 8th March, 1948. The five pilots all took part in the experimental training. These early experiments were extremely valuable, since they showed that

(a) when flying completely blind, it was possible to control the S-51 under all flight conditions associated with normal speeds and in turbulent air conditions;

(b) the pilot is fully occupied in controlling the aircraft when flying blind and, hence, the information for navigation must be presented in the simplest possible way;

(c) the artificial horizon and direction indicator were the instruments of prime importance;

(d) to minimise pilot fatigue, it is important to group the instruments and position the panel in such a way that the presentation to the pilot demands the minimum of eye movement.

The conception of *blind operations* brought out the fundamental need for an *en route* navigational aid. We required something giving a simple presentation to the pilots, which was effective at low altitudes, involved the minimum of additional weight of airborne equipment, and was simple, cheap and reliable. Of the aids available, the Decca Navigator seemed to be the most likely to suit the requirements, and some trials were begun in the Yeovil area to assess its accuracy. It was found to be good, but the method of presentation employed was too complicated for single pilot use. However, stimulated by the operational requirement formulated by BEA, the Decca Company have evolved a system which gives the pilot an automatic indication of his position on a map.

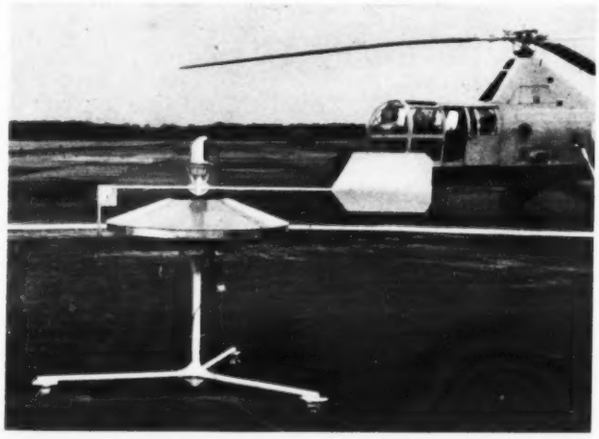
The objective of *night flying* also posed a number of problems. In order to get the aircraft to the state of satisfactory night flying, we needed a simple, cheap and reliable recognition beacon and we needed a lighting aid for approach and landing. Emergency lighting aids were also required in the event of engine failure and for ground use in the event of low visibility conditions at the terminals.

We equipped the aircraft to the full blind flying standard, so that our experimental work should not be hampered by having to fly under contact conditions at night. Red lighting was provided for illumination of instruments and cockpit fittings and in the early flying it quickly became evident that special means would be needed to retain clear vision for the pilot through the very extensive area of perspex which surrounds the cockpit. This tends to mist over inside under certain conditions of humidity and collects moisture on the outside when flying through mist and rain. This difficulty was overcome by coating the interior surface with anti-mist solution and the exterior with a rain repellent which has been developed by the National Research Council of Canada. (Specification No. FC-10.)

The early experiments with the identification light beacon were made with standard sodium runway lights. These were disappointing because the light was easily confused with other local lighting. A means of flashing these lights was developed by the Royal Aircraft Establishment, Farnborough, with promising results. Finally a beacon was made to meet the requirement of being visible from one mile at a height of 1,000 ft. in a limiting visibility of half a mile at night. A later development of a rotating beacon using a tungsten filament lamp and com-

A flashing sodium identification light beacon was developed and is now in production at the General Electric Company. The one shown is installed at Downham Market.

This special apparatus at the landing site enables the pilot at night to judge his vertical velocity and obtain information concerning the wind direction. It also provides an illuminated landing area with a diameter of 100 ft.



mercial studio lenses was brought to a successful stage experimentally and has been put into production by the General Electric Company.

The problem of ground illumination for approach and alighting was that of illuminating a local area so that the pilot would be able to judge his vertical distance and velocity, and also of providing information about the wind direction. A special apparatus was developed by the Unit in an attempt to satisfy these requirements in a simple way. A low power filament lamp mounted inside a barrel lens is so arranged that the light is thrown on to the ground over a circle of some 50 ft. radius. A canopy is placed above the light system to prevent glare from the lamp affecting the pilot's vision. To give wind direction a wind vane is mounted on top of the canopy and a 100 watt lamp fixed above it. This has a green filter to show the pilot the general wind direction. On the up-wind side of the wind vane is a baffle which casts a sharply defined shadow on the illuminated landing area and, hence, gives the pilot precise wind direction for the final stages of approach. This piece of apparatus has proved to be very successful and we have used it throughout our night operations.

With single engined machines, it is always necessary to cater for an emergency landing in the event of power failure. For night flying, this was achieved by equipping the aircraft with parachute flares which would illuminate a whole area and enable the pilot to select a point for landing, landing lamps being provided on the aircraft for final selection and actual alighting. The parachute flare is one developed by the Schermuly Company of approximately 150,000 candle power, burning for $1^1/_4$ mins. after ejection from the aircraft. These flares are self-consuming so that, when fired from 800 ft. above ground level or higher, there is no danger to property on the ground.

It was found that pilots were troubled by reflections from the underside of the rotor blades coming from the navigation lamps. These were eliminated by painting the inside of the cockpit and the underside of the rotor blades with a matt black paint. There is still troublesome glare from the navigation lights and exhaust when flying in cloud at night, but this can probably be dealt with very largely by moving the navigation light to a new position.

All the above work in relation to blind and night flying was brought to a stage such that a scheduled run was made over a period from the 23rd August to the 23rd September, 1948, from Monday to Thursday inclusive each week, the route being Peterborough to Downham Market and return (57 miles in all), making a landing on each occasion. The schedule was operated with a regularity of 100% and included a wide variety of weather conditions, ranging from moonlight to high winds with heavy rain. The navigational aid, which was an adaptation of the Standard Beam Approach, proved to be inadequate so that further operations had to await the development of an improved *en route* aid. This took some little time and we did not start a scheduled operation carrying live mail until the 17th October, 1949. The operation was continued for six months until the 15th April, 1950, and in the course of it 220 hours' night flying were accumulated of which 80 hours were blind flying.

The continuance of the operation to schedule throughout the winter was a very notable achievement, since high winds, rain, cloud and icing conditions were all encountered. An overall regularity of 77.1% was achieved and of this 73.5% was completed within five minutes of the scheduled time of arrival. In the early hours of the morning there is practically no ground lighting and, hence, in general no visible horizon. This circumstance accounts for the high proportion of blind flying mentioned above, much of it in very rough air due to high winds.

Passenger Service

Very quickly following the end of this operation, we undertook the world's first regular scheduled passenger helicopter service, between Cardiff and Liverpool with an "on call" stop at Wrexham. This, the Welsh Helicopter Service, started on the 1st June, 1950, and continued as a return journey in each direction until the 30th September, 1950. It is now going on as a single return journey. The overall distance of 148 miles is long for a helicopter route, but we were able to carry three passengers and their baggage within the limits of the all-up weight of the S-51. The elapsed time between departure and arrival is exactly two hours, including 10 minutes for the optional stop at Wrexham.

A GPO postman unloads mail from an S-51 helicopter operating on a night run.

The operational conditions are limited to a 500 ft. cloud ceiling over the local terrain and a half-mile visibility. Navigation is by visual means and communications are by VHF radio telephone, so that at practically every point along the route the aircraft is in touch with the ground. Arrangements have been made for a refuelling stop along the route in either direction should this become necessary as a result of excessive headwinds.

In this operation maintenance has been carried out on a progressive system, so that parts of the 25-hour, 100-hour and 200-hour check inspections are being done daily, the work being so sub-divided that the full schedule of maintenance is completed when the various checks become due, except for certain major components. These are dealt with by removal and immediate replacement by spare parts, the removed part being sent to the base at Peterborough for inspection and overhaul. By this manipulation of the engineering work, it is possible to fly at a fairly high rate of utilisation using only three aircraft, enabling one to be available nearly all the time as a standby.

During the summer months, a total of 393 flights was made on this service, producing 7,289 revenue passenger miles. The load factor was only 44%, reflecting the low traffic potentialities of this route. The figures for regularity and punctuality were most encouraging, the former being 96.5% and the latter averaging about 88% for departure and arrival.

The passenger reactions have been most interesting. We have had a high proportion of the passenger comments cards completed and, in general, the comments are in favour of making the journey by helicopter. The main reason for flying was to save time. Only about 3% of passengers said that they would never use the helicopter again,

A passenger helicopter service was inaugurated by BEA between Liverpool and Cardiff on June 1st, 1950. Picture shows a ground hostess accompanying the three passengers to their aircraft at Liverpool Airport.

While the dummy mail, real mail and passenger experiments were going on, BEA was repeatedly called upon to carry out special charter operations. *Left :* In May, 1949, an S-51 of BEA was contracted to lift 30 tons of equipment and materials from a Welsh valley near Portmadoc to Croesor Dam on a small plateau in the mountains. The dam urgently needed repairs, but the position was so inaccessible that not even pack mules could be used. Carrying about 4 cwt. the whole of the material was lifted to its 1500-ft perch in just over a week. Picture shows the S-51 after take-off in the valley with bags of cement in a sling.—*Right :* A Bell 47 helicopter of BEA on a crop-dusting demonstration.

whereas well over 50 % expressed their intention of using it always in the future. There were many favourable comments about the view; unfavourable comments primarily referred to vibration, and there were a number of complaints about the nose-down attitude in which the aircraft flies.

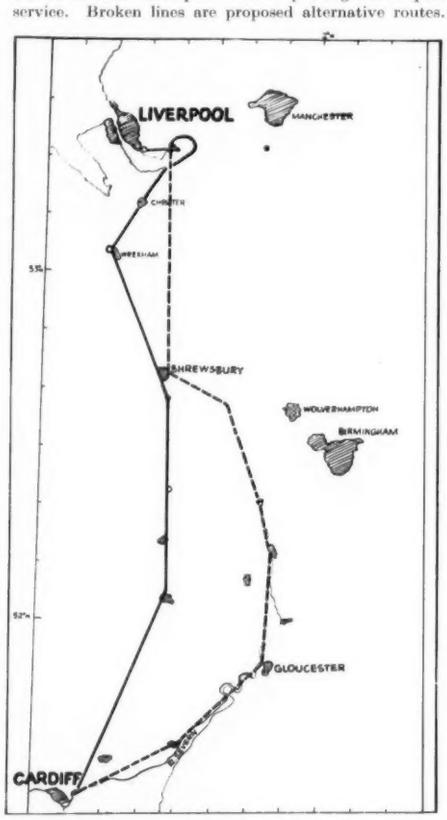
It is interesting and significant that after overhaul of the two aircraft, which became due during the service, the complaints about vibration ceased, implying a more frequent adjustment needed of certain parts particularly sensitive to vibration.

The regularity in the winter service so far has been considerably interfered with by low cloud and poor visibility, but not often by excessive winds. It is noteworthy that with multi-engined equipment which can be flown safely in cloud and out of sight of the ground, regularity would have been extremely good since on very few occasions was it not possible to take off or alight due to weather conditions at the terminals.

All our operations have shown the handicap of the single engine; without multi-engined reliability, one cannot penetrate into built-up areas for the city centre operation for which the helicopter is so well adapted; one cannot fly in cloud without being certain that the cloud ceiling is sufficiently clear of the local terrain to make a forced landing possible in the event of engine failure; one cannot operate under conditions of low visibility for the same reason. This handicap has been shown up most strongly in the operating regularity of the Welsh Service.

Thus, we look forward with the greatest anticipation to the advent of multi-engined helicopters, since we are already satisfied of the feasibility of conducting city centre operations with these aircraft with a very high degree of regularity. At present there is the prospect of only one British twin-engined type, namely the Bristol 173, being available for operations during, say, the next three years. This aircraft should fly very soon, but there will doubtless be a considerable period for experimental flying, development and finally building up production. It seems a great pity that having reached the stage in operations achieved, we should have to wait so long for really suitable equipment.

The route of the Liverpool—Cardiff passenger helicopter service. Broken lines are proposed alternative routes.



Future Prospects

At this stage it is not easy to say just when the helicopter is likely to be a sound economic proposition in Great Britain from an operator's standpoint. It is probably true to say that so far as the helicopter is concerned we now stand where aeroplane development stood in the middle-'twenties of this Century. Great advances in design and engineering lie ahead, and a great deal will therefore depend on the engineering factors as well as upon the provision of cheap landing facilities at city centres, the traffic demand and so on, but it does seem that for the purpose a fairly large aircraft of the order of 20-25 seats is needed to be sure of a profitable venture at acceptable fares. In the writer's view, such aircraft or even larger ones will be conducting the major internal air movements in this country and also, perhaps, to the nearer capitals on the Continent in ten to fifteen years' time. This facility in transport made possible by this new vehicle will steadily work a new revolution affecting all our ideas about distance and time and ultimately the internal organisation of industry and trade. What is needed now is to push forward as hard as we can with that which is now in sight and, at the same time, back it by a much greater effort in research and the related development. Thus, the basic knowledge for the design, construction and operation of the larger machines will be available in good time to enable the designing firms to provide the operators with really efficient equipment capable of achieving a very high standard of regularity at cruising speeds of not less than 150 m.p.h.

Automatic Control for Helicopter

The XHJP-1 prototype of the Piasecki "Retriever" hovering on automatic control. Both pilots have their hands outside.

Early in February 1951 the Air Materiel Command of the USAF reported from its headquarters at Wright-Patterson AFB (Ohio) that successful flight tests of automatic steering equipment for helicopters had been made. The actual helicopter types used were not revealed, but were presumably the standard USAF Sikorsky or Bell single-rotor types.

Five months earlier, on 16th September 1950, a US Navy helicopter flew entirely automatically with the aid of a modified A-12 gyropilot made by the Sperry Gyroscope Company. This pioneering achievement was carried out by a twin-rotor Piasecki XHJP-1, the prototype of the HUP-1 "Retriever." The flights with automatic control included hovering, cruising at speeds of up to 95 m.p.h., co-ordinated turns and even landings. Two blind landings with GCA approach were also carried out at Willow Grove Naval Air Station.

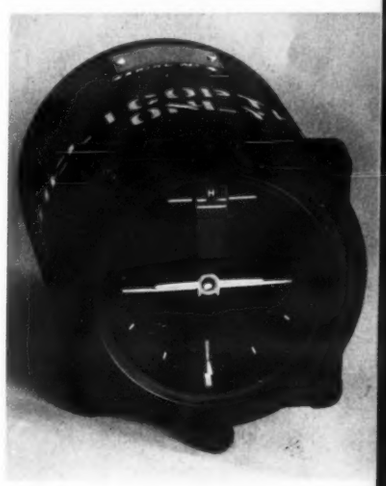
Two pieces of news like any others? By no means—The introduction of automatic control into helicopter flying is nothing less than revolutionary. The helicopter has been known as very "capricious" to fly and has frequently been the despair of even the most experienced of fixed-wing pilots. Now it will be easier to fly even than a Piper "Cub." Once a helicopter with this new equipment is in the air the pilot need merely set the desired course and optimum cruising speed... and relax. This means he has time to devote himself to such other important, though secondary tasks as navigation, communications and the like. Even long periods of flying blind do not cause excessive fatigue. To carry out rapid manœuvres the pilot switches off the gyropilot and operates the controls manually.

*

In order fully to appreciate this innovation it must be remembered that helicopters normally suffer from a lack of stability[1]. They have a distinct tendency to swing about their transverse axis; but they also roll and yaw. The pilot must therefore constantly be using his hands and feet to keep his machine in the right attitude and on the right heading. Apart from this he has an extra flying control to manipulate, the collective pitch lever. This control frequently alters the torque and thus reacts on the "rudder" setting. Finally there is a greater time-lag in response to the controls of a helicopter than in a fixed-wing aircraft. The pilot must therefore "anticipate," i.e. when correcting attitude or heading make allowance at the same time for the speed of the correction.

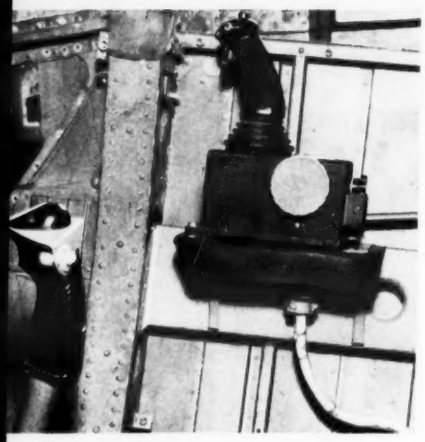
All these qualities make flying more difficult even in good weather, not to mention at night and in blind flying conditions. Gyro instruments are of course indispensable in night and blind flying, since the pilot must at least be able to ascertain attitude and heading without delay, so that he can correct them—though here some delay is inevitable. But even then such heavy demands are made on the pilot's senses, his hands and feet and not least his judgment, that even the most experienced cannot fly blind for much more than half an hour.

Nevertheless Sikorsky S-51 helicopters have been flown at night, including short periods under blind flying conditions, by British European Airways since the spring of 1948. Here good results were obtained with a pneumatically-driven gyro horizon developed especially for helicopters by the British Sperry Gyroscope Co. Ltd. This instrument was regarded as so important that two were fitted. A gyro compass was used for maintaining course. A number of warning lights (for oil pressure etc.) simplify the pilot's task of



Sperry pneumatic gyro horizon for helicopters. The top knob permits allowance to be made for the desired mean longitudinal attitude of the helicopter (within limits of $\pm 5^{o}$) by raising or lowering the aircraft symbol on the dial. The lower knob alters the reference plane for the angle of roll (also by $\pm 5^{o}$). The instrument indicates pitching within a range of $\pm 60^{o}$ and rolling of $\pm 90^{o}$.

[1] The only exceptions are Hiller helicopters (thanks to their ingenious aerodynamic system) and, within certain limits, Bell's (with a gyro system).



The Flight Controller of the Sperry A-12 gyropilot has a hand grip which can be moved in any direction and trimming controls for pitch and roll.

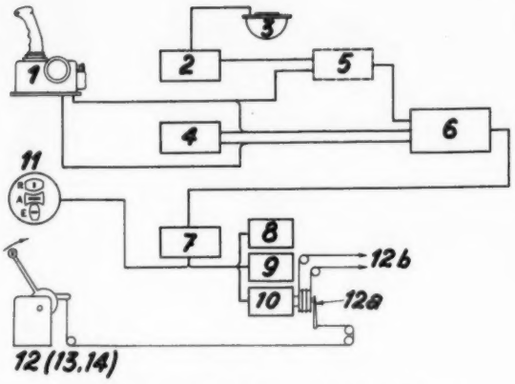
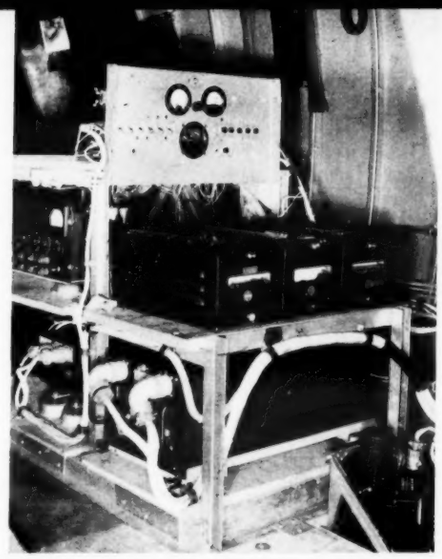


Diagram of the modified A-12 gyropilot for helicopters.

1. Flight controller
2. Directional gyro
3. Flux valve
4. Vertical gyro
5. Turn control
6. Amplifier
7. Servo control
8. Roll servo
9. Pitch servo
10. Yaw Servo
11. Trim indicator
12. Engaging control for yaw servo with cable drum release (12 a) and control cables (12 b)
13. Engaging control for pitch servo (as 12)
14. Engaging control for roll servo (as 12)



Installation of gyropilot and a number of flight test instruments inside a Piasecki XHJP-1 helicopter.

watching the various instruments. Although no particular difficulties were experienced on night flights in clear weather, blind flying for more than about 20 minutes was mentally and physically very tiring for the pilot. This is explained by the fact that attitude and course alterations are usually watched and corrected much more carefully in blind flying than in contact flying, so that greater concentration and even physical strain is required of the pilot. It has not yet been possible to make pure blind landings from instrument readings.

Thus a really satisfactory solution of the problem of all-weather flying—by day and night and in all weathers—could only be provided by a form of automatic control[2].

*

Thanks to the progress made by the American instrument industry in automatic control equipment during recent years this requirement has now been met. The Sperry A-12 gyropilot enables deviations from the required course and attitude, and the speed at which corrections are made (rate of response) to be ascertained and altered. It is therefore capable of correctly anticipating all manipulations of the controls and need only be adapted to the special requirements of the helicopter. It has also proved extremely satisfactory in commercial transports, bombers, jet fighters, robot aircraft and even in blimps.

The attached diagram shows how the A-12 helicopter gyropilot works. Two electrically-operated gyros—a vertical gyro (with vertical axis) and a directional gyro (with horizontal axis)—provide a fixed three-dimensional system of reference for attitude and heading. The vertical gyro provides two axes for ascertaining pitch and roll, and the directional gyro one (for yawing). As, owing to secondary influences, the directional gyro can maintain its position in space only for a limited period, it is synchronised with the direction of the earth's magnetic field by means of a Flux Valve[3], so that its axis of rotation is always North-South. If the helicopter deviates from the attitude set and the required course, the electrical measuring equipment attached to the gyros produces signals which are proportional to the error determined by the gyro but also allow for the speed of correcting this error. As the original current is very weak, they are amplified electronically before being passed to the servo units of the automatic control—which replaces the pilot's hands and feet. These servos are a modified form of Ward-Leonard drive, consisting of a generator and a motor. The amplifier output controls the field excitation of a DC generator, which in turn supplies the electro motor of the "control machine" with power. Separate servos are provided for longitudinal and transverse movement of the cyclic pitch control, and for torque compensation (i.e. correcting yawing movements). The three servos have a common co-ordinating device.

As the servos are coupled in parallel with the control system, any rotation of the yaw servo also moves the two pedals, and rotation of the two other servos the main stick. When the Gyropilot is switched on, the pilot allows all controls to move freely and steers the aircraft simply by means of the Flight Controller grip which is fitted to the right of the main stick and remains in any position set. He must of course at the same time keep his eye on the setting of the collective pitch lever (and throttle) and correct it when necessary. The base of the Flight Controller also contains the main switch for the electrical system and two small trimming controls for pitch and roll. Movement of the hand grip in the fore-and-aft direction alters the longitudinal attitude of the helicopter as required. Each lateral setting produces a definite angle of bank and starts a turn at a corresponding rate-of-turn.

*

All the pilots who have flown the automatic Piasecki XHJP-1 are enthusiastic: they report complete stability at all speeds without fatigue. The pilot's full attention can be given to all kinds of secondary tasks for periods of several minutes. Forward and backward flying, co-ordinated turns, hovering can all be started by simple pressure on the flight controller. Even if the helicopter is disturbed by gusts it always returns to the attitude originally set. And radio-controlled blind landings are now child's play, for in addition to the advantages of automatic control during approach, it is possible to reduce forward speed and speed of descent to zero.

There is already talk of fitting multi-place helicopters with radio navigation aids, for example the 1500 h.p. Piasecki H-21 now under development which is designed to transport 20 fully-equipped troops and for rescue missions in the Arctic and is at any rate to be fitted with automatic control.

Finally, however, it must be admitted that the A-12 Gyropilot, which today costs roughly $8000, is an expensive little item. But the helicopter itself is not exactly cheap, and the extra expense of an automatic control which so greatly enhances not only the military value of the helicopter but also its usefulness as a civilian transport will doubtless be justified. Anyway it is reported that over 100 Sperry A-12 Gyropilots for helicopters have been ordered by the US Navy and Air Force.

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[2] The importance of anti-icing equipment should be mentioned here ; cf. article by E. J. Katzenberger on p. 159 of this issue.

[3] The Flux Valve (or Flux Gate) replaces the magnetic compass. It is very small and so can be fitted in a small space, i. e. away from the aircraft's own magnetic influences. It consists merely of a fixed star-shaped iron core with a few wire windings, and provides constant information on the position of the earth's magnetic field by an electro-magnetic process. This information is transmitted electrically to the directional gyro.

A PROFILE

Young Mr. Hillercopter

BY SCHOLER BANGS, LOS ANGELES

Ask Stanley Hiller, Jr., for his choice of a portrait photo to go with a story about his helicopter career—and what does he give you? A "nice" picture, radiating dignity, of himself sitting behind a clean, polished desk for all the world like a corporation president—which, of course, he is. But I think that ten years from now Mr. Hiller will chuckle in amusement at the portrait. I think he'll see himself in a montage of three snapshots, widely separated in years.

The first was taken on May 14th, 1944, and you don't see young Mr. Hillercopter in it at all. You see a small cabin co-axial helicopter lurching over, drunkenly, on the driveway of the Hiller, Sr., estate in the hills above Berkeley, California. One rotor blade has just dug into the adjoining lawn, and clods of dirt are flying. Project the photo three seconds, and you see the little machine threshing on its side, rotors chewed off, the distant hillside spurting dust from the impact of bits of rotor blade. That was his first attempt to fly his first "Hillercopter" at the age of 19.

You see him more clearly in the second picture, sitting with a mechanic in the flight test frame of what was intended to be the sell-like-hotcakes "Hiller Commuter." To all appearances young Hiller, on the verge of success, fame and fortune, is sweeping into a low-level tight turn against the photogenic backdrop of California's pleasing landscape near his new Palo Alto factory, just south of San Francisco. But the photo is misleading. The framework test machine you see is out of control. It is falling. It is in the last of a series of wild, dizzy pendulum swings. One second, maybe two, more and the machine will be a wreck, and Hiller and mechanic amazed that they're unhurt. With it crashed Hiller's dream of the co-axial helicopter. Age, 22.

Now look at the third picture. The serious young man in the lower machine is Stanley Hiller, Jr., aged 25. It portrays a man who has shaken off the ashes of diaster and feels more at home where he is than behind a presidential desk. The "Hiller-Hornet" he is flying is the first experimental production design of the first ram-jet helicopter built with an eye on commercial markets. A machine which has the "inherent stability" paddle-rotor control that saved his company from ruin and made the "Hiller 360" production model possible; a machine which he thinks he can build and market for less than

Stanley Hiller's favourite portrait. He prefers the engineering side of his job, however.

$5000 when military orders for other work ease up.

Some of the oldsters among the stockholders of his United Helicopter, Inc., recently re-named *Hiller Helicopter Inc.*, are banking on young Hiller winding up as the "Henry Ford of the Aircraft Industry." There is one among them who recalls that once he owned a fair number of shares of Henry Ford stock, and let it go; stock which today would have made him several times a millionaire. Today he holds Hiller shares which, although they have yet to pay their first dividend, he is hanging on to for dear life, and will pass on to his heirs with the admonition that they do the same.

Stanley Hiller realises—and so do his competitors—that if the aircraft industry ever is going to reach the pocket and purse of the main-in-the-street it will have to be done by giving him something he can fly without breaking his precious neck; something so mechanically simple he can keep it running with the tools in his garage; something he can buy on the instalment plan from his weekly paycheck.

Three-minute engine change can be effected with the quickly detachable eleven-pound ram-jet unit of the "Hiller Hornet."

Hiller aimed the "Hiller-Hornet" in that direction. Moving parts are held to the minimum in the hub-control system. Rudder pedals are gone, the rudder integrated with movement of the control column. It's directional control is finger-tip sensitive, and with controls adjusted the "Hornet" will amble along at 70 miles an hour without the necessity of touching the control column. It is designed to carry two people plus 25 pounds of baggage 50 miles at cruising speed, and climb at 1200 feet per minute. Its 11-pound ram-jet engine, good for 500 hours of running, can be replaced in three minutes.

Buzzing about the factory grounds, it looks like the accomplishment of an inventive genius—a description Hiller seems to loathe. He is an inventor, but he also has an uncanny ability to pick the brains of others and make the best of what he finds. In his factory office, behind that glittering desk, he told me, nevertheless:

"I'm NOT an inventor. I'm simply a junior manufacturer, I just have the itch to make things, and make them pay off. I feel as if someone is prodding me all the time..."

The helicopter industry was still tagging him as an exuberant young "inventor" about the time the second crash landing picture was taken. A few months later helicopter manufacturers were rocking on their heels from the impact of a photograph of Hiller's "inherent stability" test machine hovering with nothing but a sandbag in the pilot's seat.

How did Hiller start on his career? It was in the fall of '45 that a dark-haired, twenty-year-old youngster was visiting, one after another, the offices of high finance on Wall Street. The way secretaries hastened to usher him into the presence of the Street's money masters would have suggested that he was a favored somebody's son. Actually he was merely a hinterlander from California who had wangled a few gilt-edge introductions, and who was saying, "All I need is two-and-a-half million dollars!" With the burning intensity of youth, young Hiller explained that the sum would be enough to set him up in the manufacture of a helicopter he had designed.

"All I got," Stanley Hiller recalls, "was the worst kicking around I'd ever experienced. Whatever had given me the idea that anyone would put risk capital into anything like that? Didn't I know that aircraft plants,

Three snapshots, widely separated in years. *Left :* May 14th, 1944 : Hiller's unsuccessful first attempt to fly his first "Hillercopter." *Centre :* 1947 : The would-be test machine of the "Hiller Commuter" co-axial helicopter a second before it crashes. No-one was hurt, but Hiller's directors said "No" to his further test flying. *Right :* 1950 : Hiller flies the first experimental production model of the "Hiller Hornet" ram-jet helicopter which also incorporates the "inherent-stability" paddle-rotor control which made the "Hiller 360" utility helicopter possible. Absence of torque eliminates necessity for rudder pedals and provides a simple "two-control" helicopter. Direc-

with their wartime contracts cut off, were going broke right and left? Without military subsidy where would I be? And how did I, a boy, expect to compete with veteran manufacturers who'd been doing business for years? I just couldn't get it through their heads that I was a junior manufacturer in my own right. To them I was an 'inventor', the anathema of Wall Street. To make matters worse, I was a 'kid inventor'..."

Today, with little left of the bitterness he must have felt at the time, Hiller can tell about it with considerable relish.

Undeniably he had been a precocious mechanic during the 'teen years he was just then trying to put behind him. He had conceived a model gunpowder rocket plane when he was nine and unwittingly had given it, years ahead of its time, a sweptback supersonic wing that carried the flame-spewing missile into oblivion over the tops of the Berkeley hills behind his home. He had bolted a model airplane gas engine into a toy race car and started a new model-building craze. With help from his father he had invented (and received a basic patent for it), an aluminium die-casting machine. There was a greaseless aluminium skillet for housewives. And a helicopter that was different from any that had ever been built.

It was equally true that he could stand firm on his "junior manufacturer" claims. To the rythmic bump-thud of his diecasting machine the model racer of his creation spurted out of the plant of Hiller Industries at the rate of 10,000 a year, and gave him an annual gross profit of $100,000 when he was fifteen. Shortly before Pearl Harbor the War Department handed him the first contract issued for production of a new hexagonal-tube magnesium fire bomb; establishing him, at the age of sixteen, as the world's yougest munitions maker.

Wall Street had been the final hunting ground. He had already tackled the financiers on Montgomery Street in San Francisco; on Spring Street in Los Angeles. Not interested! The fabulous Western industrialist Henry J. Kaiser had been fascinated by Hiller's first helicopter, and had watched the nineteen-year-old "inventor" fly it on the football field of the University of California stadium in Berkeley. In a brief alliance, Kaiser had backed him in building two sample models of a closed cabin version. But Kaiser called it quits when Stanley informed him that it would take close to three million dollars to smoke the "bugs" out of the design and get it into production.

Back home from New York, empty handed, the only thing left for Hiller to celebrate was his twenty-first birthday. Profits from his diecasting business and the ultimate sale of it had all gone into building his first helicopter, and into rebuilding it each time it crashed. Money from the Kaiser deal was almost gone. It looked as if he would just have to forget it, and give final paychecks to the nucleus of engineers he had gathered together, hopefully, in a little research laboratory. He didn't realize that across the Bay, in San Francisco, there was a waiting gold mine.

Almost hesitantly his laboratory purchasing agent, Arthur McGee, asked if Stanley would object to his telling his father-in-law about his problem. He was Edwin Street, who shared with Joseph E. Biallas the ownership of an Oakland investment banking firm, Capital Securities Co. The results of their meeting cause other aviation industrialists to shake their heads in amazement to this day, and have tagged Hiller as the luck-plastered promoter.

Left : In a brief alliance Henry J. Kaiser, well-known production wizard, backed Stanles Hiller; here he is shown, with Hiller, inspecting the ill-fated but rebuilt "Hillercopter" in September, 1944.—*Right :* Kaiser called it quits when Hiller told him, after building two samples of a closed cabin version, that it would take $3,000,000 to work the bugs out of this proposed "everyman's helicopter."

tional control is obtained by moving collective-pitch lever horizontally which actuates "Hornet's" conventional-type rudder.

heavy initial production payroll. This was done by having parts subcontractors throughout the nation build more than 90 per cent of the machine's component parts and ship them to Palo Alto for assembly. He also organized distributors not only for domestic markets but also in France, England, Switzerland and other countries.

Back of all this is the canny planning of an "industrialist" mind at work. What is more, Hiller certainly has had an unusual amount of luck. Another look at the photo of Hiller and his mechanic about to crash in his co-axial "flying test stand" will tell you why. Almost every penny of the corporation's liquid capital had gone into it. The first experimental models of the production "Commuter" were nearing completion; one, in fact, had already flown. You might say that in the wreckage of the "test stand" the entire million-dollar project, and the company itself, lay in ruins. It looked like the end of the precocious Mr. Hiller! Desperately, Stanley Hiller threw together another experimental machine —conventional this time, with a single rotor, tail boom and tail rotor—which rolled over on its side in an attempted test flight.

Control was the problem, and a discouraging one. In a skull session between Hiller and his engineers, someone remembered earlier paper designs for gaining aerodynamic control by mounting two small "paddle" rotors at right angles between the two main rotor blades. The pilot would control the paddles, and they, in turn, would control the attitude of the rotor disc by gyroscopic precession forces. Hiller recalls that he would have been satisfied if it only gave the pilot an opportunity to catch approaching instability before it became catastrophic.

"We could hardly believe what we saw," he says of the first test flight of the paddle control system.

Above them Frank Peterson, his chief test pilot, brought the helicopter to a mid-air hovering standstill, took both hand soff the controls, elaborately hunted through his pockets for a cigarette, and then just sat there, smoking and grinning.

Luck? You said it!

The helicopter industry's will-o'-the-wisp of "inherent stability" was up there in that hovering little framework. Looking back, Peterson recalls the flight with a pilot's appreciation: "I'd never before been able to enjoy a cigarette while flying a helicopter. I was always too damned busy keeping the thing rightside up."

Hiller puts it this way: "It was just like being handed a million dollars—tax free."

Hiller briefly tried a jet system as a substitute for an anti-torque.

This was the much-talked-of Hiller "Commuter," which was shelved when the framework test model went out of control and crashed.

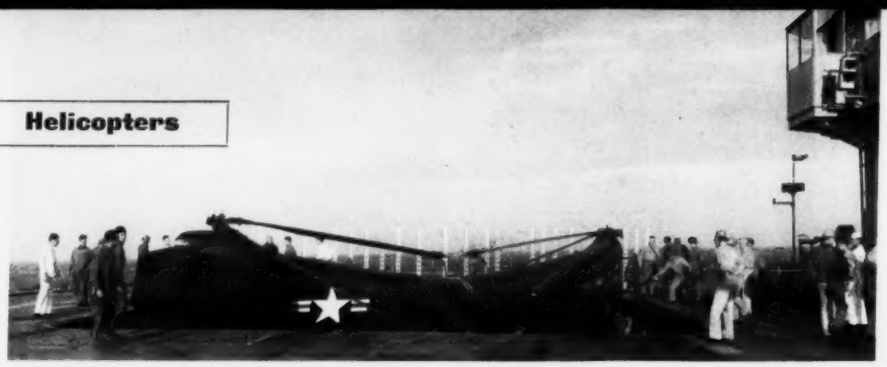
What Biallas and Street sensed, and Hiller had overlooked, was that San Franciscans are irrepressible romanticists and that sometimes they do the damnedest things. Without batting an eye they'll give a serious, gangling youth, just turned twenty-one, a million dollars—in cash. And when that is used up, they'll do it again, but bigger. Say a million-and-a-half the second time around. Hiller says: "They're wonderful!" In less than four months after Capital Securities helped him organize United Helicopters, Inc., they had bought to the last ten-dollar share, and on sheerest speculation, a million dollars worth of stock.

For their first million, Hiller's stockholders received not one, but *eight* experimental helicopters, including prototypes of three separate designs; a choice, 61-acre factory site; a $150,000 factory building; $100,000 worth of experimental tooling; and a payroll studded with the names of the nation's top helicopter engineers.

For their second contribution, a million and a half, Hiller evolved his inherently stable "360"; brought it into production, and evolved a plan by which Helicopters Inc. could sidestep the back-breaking load of a

No hands, no pilot! The "flying test stand," which first demonstrated the feasibility of Hiller's "paddle-control" system. Publication of this picture showing an "inherently stable" helicopter caused a sensation in the USA.

The "Hiller 360," a conventional helicopter with a tail rotor but incorporating the "paddle-control" has been in quantity production for some time and is being used for a variety of purposes. Here is a marine version used for spotting tuna fish.



The US Marine Corps School at Quantico, Va., is developing tactics and techniques for helicopter-borne assault landing forces. Picture shows an elevator on the carrier "Palan" lifting a Piasecki HRP-1 helicopter from the hangar deck to the flight deck in preparation for the assault. Note folded rotors.

Eight HRP-1's are placed on the flight deck of the 12,000-ton escort carrier "Palan," now used for training. Aircraft carriers would be widely dispersed to avoid presenting a single target for an atomic attack.

A patrol of fully equipped Marines is carried to a predetermined landing area, by-passing strong beach fortifications. The helicopters would operate under fighter protection. Fewer troops would have to pass across heavily defended beaches, and shipping could remain dispersed at sea.

The "Egg-Beater" Goes to War

One might have thought that the helicopter was *the* aircraft which could never be used for aggressive purposes and would always concentrate on the performance of peaceful chores, such as the carriage of mails and passengers over short distances, ambulance and rescue operations in remote or inaccessible regions, in the Arctic and in tropical jungle areas, dusting and spraying of fields, forests and orchards, and the evacuation of wounded. Unfortunately the human mind has never been able to resist the temptation of investigating the war potential of any new contraption, no matter how peaceful its inventor's intentions may have been.

In this respect the helicopter has not fared better than the aeroplane or the motor car or the early Chinese rocket. The World's Navies are interested in it, and so are armies and air forces. What they want to use it for is no longer a secret. The US Marine Corps has been conducting large-scale experiments with helicopter-borne assault troops, which can be landed at precisely determined points far behind enemy lines to carry out whatever tasks are assigned to them. The British Royal Navy at the end of January carried out tests with helicopters for the defence of merchant ships and sea communications.

In London Vice-Admiral M. J. Mansergh, Fifth Sea Lord and Deputy Chief of Naval Staff (Air), told members of the Royal United Service Institute on November 8th, 1950, that the British Navy was studying the helicopter with a view to using it as a short-range unarmed search aircraft to deal with submarines eluding the normal search and getting ready to attack. It would have to be equipped with a sonobuoy receiver, since it would be tackling mainly submerged submarines. In addition, it would have to have good communications with surface craft, and later it might carry its own anti-submarine weapons. Corresponding trials by the US Navy, Vice-Admiral Mansergh said, showed encouraging results. The same aircraft could also be used for communications duties from ship-to-shore and ship-to-ship.

While the patrol advances, the helicopters return to their aircraft carriers to bring up either supplies or reinforcements.

One helicopter has landed, another is about to alight. One patrol of combat troops can be disembarked in twenty seconds. Surprise in the approach and choice of landing areas are advantages of helicopter assault.

Within one minute after air delivery, the gun crew is ready to fire its howitzer.

Additional ammunition and equipment is flown in.

The Army's helicopter requirements were defined recently before the Helicopter Association of Great Britain by Major-General R. H. Bower, Director of Land/Air Warfare at the British War Office. Three types of helicopter would be needed by the Army in future, the General said. The first is a *light two-seater* for artillery spotting and observation in areas where no airstrips are available. The second is a general-purpose *four-seater* destined primarily for evacuation of casualties, for jungle, Arctic and sea rescue duties, communications and movement of commanders and staffs. Finally, there will have to be a *heavy lift helicopter*, with a payload of three to five tons, and a range of about 300 miles, for the landing of troops and stores from ships in combined operations, for *coup de main* operations, the quick forward movement of bridging material, crossing of minefields and rivers, etc.

Helicopters operated by the Army must be much easier to fly than present types. They will be flown by Army pilots, but it may not be possible to provide trained officers for this purpose, and the pilots will be mainly sergeants of the type that used to fly the troop transport gliders in World War II.

It seems that the provision of the first two types will offer no excessive difficulties, but the heavy-lift helicopter is another proposition. It is very vulnerable, even to small-arms fire, which limits its tactical use, and it will be very expensive to produce and to maintain. Moreover, its military advantages cannot yet be determined with certainty.

The exercises which the US Marine Corps has conducted in the past few months—as illustrated on these pages—will provide a partial answer to some of these problems. The tactics employed in the manœuvres are based on the following assumption: carried by ships widely dispersed off-shore, the helicopters load assault troops and fly in from different directions, circumventing powerful beach defences, and land accurately in any desired position and formation.

But even the Marines' proverbial enthusiasm for their new vehicle has already been tempered by experience. A Department of Defense release points out that, "like other means of amphibious assault," helicopter employment has certain handicaps, namely, the present restricted load capacity, range-speed and mechanical reliability. It adds that such technical limitations can be expected to be overcome in the process of further development.

The result will be an important addition to the multitude of modern tactical weapons and the "egg-beater" will have added a full-dress martial rôle to its present non-combatant duties.

Returning to more humanitarian duties, the helicopter prepares to pick up a wounded Marine for return to his ship for hospitalization.

The helicopter is back again preparing to effect a "Special Airmail Delivery" of a 75-mm pack howitzer.

In wooded areas where actual landing is impracticable, a wounded man can be hoisted up into the hovering helicopter.

What's in the Air?*

Nobody could maintain that Eisenhower conducted his conference with European Defence Ministers and General Staffs in a high-handed manner. The General's capacity for diplomacy contributed equally as much to the Allies' final victory in World War II as did his far-sightedness and energy. Nevertheless, his recent tour of Europe has had prompt and enduring results and has left behind the feeling that the period of "marking time" by the Atlantic Pact military organization is now at an end.

A small example will suffice to illustrate this: Two years ago the establishment of Western Union Headquarters was accompanied by endless wrangling over personnel and location (Fontainebleau).—Today the technical details have been worked out without any of this fuss and bother, and the statements made have been concise and unemotional: General Eisenhower has set up his headquarters at Versailles. There is to be a forward headquarters in the German town of Heidelberg. Members of Eisenhower's staff are to include the new Inspector-General of the French armed services, General Alphonse Juin, and the present Commander-in-Chief of the Western Union forces, Field Marshal Montgomery.

Considerable military reorganisation has also taken place almost as quietly (except in Holland where the dismissal of the Army commander was the direct cause of a cabinet crisis). Air Chief Marshal Sir James Robb has been replaced as Commander-in-Chief of Western Union air forces by Air Chief Marshal Sir Hugh W. L. Saunders; Marshal of the Royal Air Force Lord Tedder's place as Chairman of the British Joint Services Mission in Washington is to be taken by Air Marshal Sir William Elliot, at present Chief Staff Officer to the Ministry of Defence, and so on. In Holland the Commander-in-Chief of the Army, General H. J. Kruls, has been replaced by Rear Admiral E. J. van Helthe, formerly Chief of the Naval Staff.

Even more important than these changes in personnel are the organisational measures taken. At last the outlines of the future Atlantic Pact Army are beginning to emerge. On his return to Washington to report to the Senate, Eisenhower stated that he planned to create a European force of 40 divisions, 15 of them French, by the end of 1952. The strength of American reinforcements would be adapted to European requirements. As was to be foreseen the isolationist wing of the Senate did not accept this statement without protest; however General Eisenhower was energetically supported by General George C. Marshall, the American Defence Minister, who answered the question of whether Europe could be defended with a very definite affirmative.

Per A. Norlin, President of the Swedish air transport company ABA, was elected *President of SAS* when the reorganization of this System was formally concluded (on 8th February in Oslo).

*

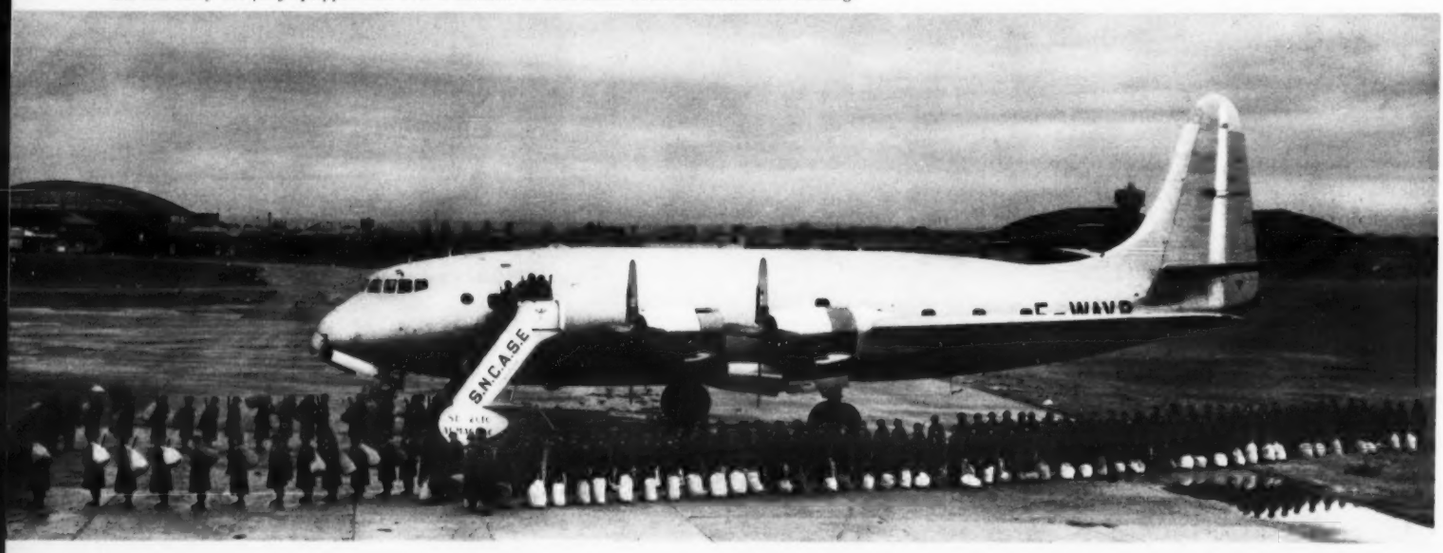
Within the framework of the projected increase in US forces in Europe from 2 to 6 divisions (approximately 120,000 men), a large-scale reorganisation of USAFE (United States Air Forces in Europe) is being undertaken. On 24th January 1951 it was announced in Washington that the 12th Air Force is to be reactivated under the command of Major General Robert W. Douglass. It will comprise all American air forces in Germany and Austria. USAFE is in future to include the 12th US Air Force, the 3rd (Bomber) Division in England, the American air force units in the Mediterranean area including Mellaha (Tripoli) air base, and the tactical units of the 2nd Air Division at Heidelberg. The Commander-in-Chief of USAFE, Lieutenant General Lauris Norstad (formerly Deputy Chief of Staff, Operations, on the USAF Staff), will probably shortly move his headquarters from Wiesbaden to Versailles, the headquarters of the Commander-in-Chief of the European Army, to whom he reports direct.

At the same time the USAF is taking over a number of air bases in Europe, North Africa and the Near and Middle East. For example the large RAF maintenance base at Sealand (Cheshire) was handed over on 22nd January 1951. Some 3000 USAF personnel are to be stationed there to service USAFE engines. Sealand is the sixth air base in Britain to be ceded to the USAF, and three American Boeing "Superfortress" bomber groups and one "Thunderjet" fighter group with a total of 15,000 men, are now stationed there.—Certain aviation circles in London link up the transfer of Sealand with the recent training flight of six Convair B-36's to England and forecast that a number of these long-range bombers will be based in England. Further American A/A units are also to arrive in Britain shortly.

Edward H. Jefferson, Quality Controller at Hawker Aircraft Ltd., has been made a Director of the Company.

* Extracts from INTERAVIA AIR LETTER, daily international news digest, in English and French. All rights reserved.

It is not only the Americans who appreciate the vital importance of commercial transports as reserve military transports. The *French SE 2010 built by the SNCA du Sud-Est* can carry *156 fully-equipped men* over a distance of 2180 miles without intermediate landing.



A Stone's throw: An English Electric "Canberra" jet bomber has crossed the Atlantic from Aldergrove, Northern Ireland, to Gander, Newfoundland, in the record time of 4 hrs. 37 mins. The "Canberra," which is fitted with two Rolls-Royce "Avon" jet engines, is to undergo trials in the USA to determine whether it is suitable for use by the USAF.

The Crew of the "Canberra": left to right: Flight/Lt. A.R. Robson (radio operator), Squadron Leader A.E. Callard (pilot), Flight/Lt. E.A.J. Haskett (navigation).

The question of bases was also discussed by Thomas K. Finletter, American Air Force Secretary, who stopped off in Paris on his way to Ankara to talk with General Norstad. It was suggested that the main purpose of Finletter's visit to Ankara might well have been to discuss with the Turkish authorities the possibility of America's being granted bases in the event of war. There would appear to be no question at present of taking over Turkish bases in peacetime.

ATLANTIC POWERS POOL AIRCRAFT INDUSTRY RESOURCES

Rumours that have been circulating for weeks that American, British and Canadian aircraft industries would be coordinated to provide Anglo-Saxon armaments requirements have been confirmed by British Secretary of State for Air Arthur Henderson and Defence Minister Emanuel Shinwell speaking in the House of Commons. As a first step it is proposed that about 400 North American F-86 "Sabre" jet fighters for the RAF be built by Canadair Ltd., Montreal, and fitted with Avro Canada "Orenda" jet engines, as General Electric J-47 engines are not available in sufficient quantities at the moment.

Production under licence by French and Italian firms was discussed in the article on "1951 Aviation Prospects" (INTERAVIA REVIEW, Volume VI, No. 2, 1951). In Australia too licence production is well under way. In addition to the de Havilland "Vampire" already under construction, the Australian jet fighter programme provides for the production under licence of the North American F-86 "Sabre." The Commonwealth Aircraft Corporation is also to start building the English Electric "Canberra" bomber.

The men responsible for the Anglo-Saxon countries' air armaments have evidently realised that it is no longer possible for each to go his own way under present-day conditions.

With British Government approval Armstrong Siddeley Motors Ltd., of Great Britain, and Curtiss-Wright Corporation, of American, signed a long-term agreement in New York on 25th January 1951, permitting the Americans to build the latest British engines under licence. For the moment Curtiss-Wright are to have licences for the following Armstrong-Siddeley engines "Sapphire," "Python," "Double Mamba" and "Mamba."

What seemed impossible a few months ago is a commonplace today... Under the new British long-range bomber programme, the Bristol Aeroplane Co. (makers of the giant "Brabazon" prototype) and Boeing Airplane Co. (producers of the B-29 and B-50 "Superfortress" long-range bombers) are to be permitted by their respective governments to exchange secret information.—According to a report from Bristol's, Boeing are to provide details of their research results and the two concerns will work hand in hand in future development.

In this connection an interesting development is the agreement recently signed by the British and American governments on the exchange of civilian test pilots who are to fly the newest military and civil prototypes across the Atlantic and demonstrate them to Allied industrial and military circles. Squadron Leader T. S. Wade, chef test pilot of Hawker Aircraft Ltd., will be one of the first British test pilots to be sent to the USA.

*

This co-ordination of production by the Atlantic Powers has also recently been extended to Italy, whose armament and aircraft industry is to be reactivated to enable it to supply equipment to other Atlantic Powers under the Mutual Defence Assistance Programme. The Italian government has announced its willingness to provide 100,000 to 200,000 million lire towards the cost of starting such production if the USA will supply machine tools and raw materials and provide a suitable dollar credit. Firms such as Fiat, Aeronautica Macchi, Alfa Romeo, SAI Ing. Ambrosini & Co., Industrie Mecchaniche Meridionali (who has already received government orders) and others, such as SIAI-Marchetti, Caproni Aeronautica Bergamasca (which were recently visited by the committee of experts from the North Atlantic Treaty Organization) will doubtless be the chief firms concerned in this programme. In addition new industrial groups, which will devote themselves chiefly to the construction of American aircraft under licence, are to be set up in southern Italy. Characteristic of the present desire for international cooperation is the Franco-Italian plan, reported from Paris, for joint production under licence of the British "Venom" jet fighter, under which the French SNCA du Sud-Est would make the airframes and the Italian Fiat works the "Ghost" jets.

*

Pending the realisation of these plans deliveries of American aircraft to the European Allies are to continue at an increased rate. This applies especially to the tactical aircraft so urgently required by the European air forces, such as the Republic F-84 "Thunderjet" jet fighter and ground attack aircraft, considerable numbers of which are shortly to be supplied to France and Holland. The Belgian Air Force is to receive North American F-86 E's.

William B. Bergen has been made vice-President —Chief Engineer of The Glenn L. Martin Company, Baltimore.

THE AIR TRAFFIC BOOM CONTINUES

In contrast to the usual seasonal slump during the winter, *American Air transport companies' record business* appears to be continuing almost unabated during the 1950/51 winter period. First reports for December and January show that most of the leading companies have exceeded last year's figures by at least half; *e. g.* American Airlines 50%, TWA 60%, United Air Lines 50%, National Airlines 76%, Eastern Air Lines 60%. Capital Airlines report a net profit for January 1951 (for the first time in their existence), and Colonial Airlines announce a general increase in traffic of 64%, with a 268% increase on their Bermuda services.

It will surprise no-one who is familiar with the Company's traffic figures during the airlines' crisis years that Pan American Airways should also survive the winter comfortably. Nevertheless it is interesting to compare their operating results for the third and fourth quarters of 1950 with those for 1949.

During the fourth quarter of 1950 the Company operated 14,483,617 aircraft miles and 331,652,000 passenger miles, or in other words carried almost as many passengers as during the peak season (third quarter 1950: 14,417,500 miles flown and 391,837,000 passenger miles). By comparison the figures for the last quarter of 1949 are 15,662,250 aircraft miles and only 272,414,000 passenger miles.

To all appearances the blessings of the "mild winter" have also been felt by certain companies in the Old World. Admittedly no final figures for January are yet available for the European companies, though BOAC reports that the number of passengers carried on the dollar-earning Nassau—New York service in January 1951 was 23.1% higher than in December 1950.

Air France too has reason to congratulate itself on its dollar earnings. The Company's latest report shows that 53% of the passengers on the North Atlantic services were Americans, against 25% French, and that on the South Atlantic run 52% foreigners were carried (including 13% Brazilians and 12% Argentinians).

No figures are yet available for Atlantic traffic as a whole. Early in February 1951, however, the US Immigration authorities published certain figures for the month of September 1950 which indicate a great victory for air transportation. During this one month no fewer than 54% of all Atlantic travellers crossed by air!

1951 Aviation Prospects*

Scandinavia

Commercial Flying

Air transportation in the three Nordic countries has to be treated as an entity in view of its peculiar configuration as a single supra-national air carrier organization embracing three national components under the name *Scandinavian Airlines System.*

It so happens that airline development in Scandinavia during 1951 is bound to be of great interest not only to the three countries involved, but also in the international field. Sweden, Norway and Denmark have just signed a new agreement which closely integrates their air transport operations by merging their national carriers, ABA, DNL and DDL, in a strengthened SAS.

When Scandinavian cooperation in the air transport field was initiated in August, 1946, the somewhat loosely formed SAS merely took charge of intercontinental operations. European cooperation followed in April, 1948, as a result of the merger of ABA (the Swedish airline) with SILA (the Swedish intercontinental carrier and SAS component) into a strengthened ABA.

SAS operating results from 1948 to 1950 have not been very satisfactory, largely because of the oversized administration and ground organization of the three airlines combined. All parties have now agreed to pool their resources in a commercially and operationally much more efficient manner, with the three national carriers continuing to exist as mere holding organizations of the integrated SAS. Operations will be centralized, maintenance divided between Stockholm (Douglas DC-6), Copenhagen (DC-4) and Oslo (DC-3 and SAAB "Scandia"), and the whole organization has been placed under a single Managing Director, Per A. Norlin, of ABA. Financial resources and responsibilities will be shared by the three nations in the proportion of three-sevenths for Sweden, two-sevenths each for Denmark and Norway. The air fleet now consists of 65 aircraft (DC-6, DC-4, DC-3 and "Scandia"), but several more DC-6s are on order.

In 1951 SAS hopes to operate successfully, from the points of view of both traffic and financial returns, as a result of its higher degree of operating efficiency brought about by the reorganization, combined with the continuing international air travel boom. Indications of an improvement were already available during last year: at its ordinary general meeting next May DDL, the old Danish SAS partner, will probably announce a net profit of about Kr. 2,000,000. The Swedish ABA and the Norwegian DNL also expected to declare small profits.

Norway is the only one of the Scandinavian countries to have a fairly large airline *in addition* to its national carrier. This is Braathens SAFE, which operates a fleet of four DC-4s and one DC-3; two of the DC-4s at present are flying on the Pacific airlift with American crews; the others are used on the company's weekly Hong Kong service and for charter operations.

In addition to Braathens SAFE, *Fred Olsens Flyselskap* is flying extended charter operations on the European market with DC-3s. Norway also has a relatively large number of taxi, ambulance and photographic survey operators.

So much for Scandinavia's "United Nations of the Air." In other fields of aeronautics each of the three nations acts independently. Here is what our Correspondents write.

Sweden

Aviation Authorities

Stockholm, February 1951.—The Royal Swedish Board of Civil Aviation is working on two legal questions in 1951. One is the revision of the present, outdated air transport legislation; this will not be completed this year, however. The other is a co-ordination of the Swedish, Norwegian and Danish civil aviation authorities to enable them to exercise uniform control over the new SAS.

The Government will also concentrate on the expansion of the major Swedish airports, notably Gothenburg-Torslanda and Malmö-Bulltofta. Some progress will also be made with the work on the new Swedish trans-Atlantic airport at Halmsjön, but owing to insufficient funds construction will proceed at a leisurely peace.

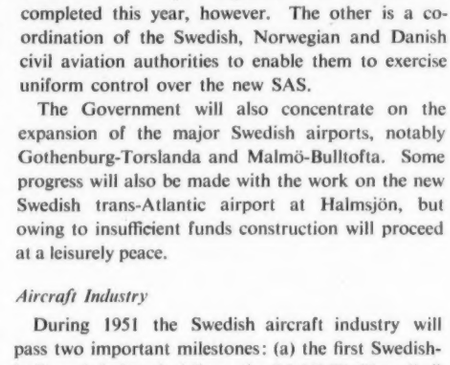
Aircraft Industry

During 1951 the Swedish aircraft industry will pass two important milestones: (a) the first Swedish-built and designed airliner, the SAAB-90 "Scandia," will enter scheduled airline service; (b) the SAAB J-29 transonic jet fighter will go into squadron service with the Swedish Air Force.

The contract for the SAAB J-29 is reported to be the largest ever placed by the Swedish Air Force, and the figure of 500 aircraft has unofficially been mentioned on several occasions. However, it is a known fact that these large military orders are causing considerable difficulty to *Svenska Aeroplan* AB, Sweden's only aircraft maker (and the only major manufacturer in Scandinavia), at the expense of the production of the company's promising civilian projects, the "Scandia" airliner and the "Safir" three-seater personal and training aircraft. In order to "save" the two types, SAAB is negotiating for their production under licence in countries whose industry is not snowed under by military orders. For the "Scandia" negotiations are under way with the Italian Fiat concern.

Another important event in the Swedish aircraft industry is the recent agreement between *Svenska Flygmotor* AB and *Svenska Turbinaktiebolaget Ljungström* (STAL) for the joint development and production of jet engines. Since November, 1948, Svenska Flygmotor has been building de Havilland "Goblins" and "Ghosts" (the latter for the SAAB J-29). First on the SFAB-STAL programme is the quantity production of a new STAL axial-flow engine for a new jet aircraft scheduled to replace the J-29 on SAAB's assembly lines. The engine will be considerably more powerful than the 5,000-lb.-thrust "Ghost."

Stockholm : Parliament.



Service Aviation

Is has always been the intention of the Government to make the country self-sufficient as regards military aircraft, and Swedish Air Force prospects for 1951 are therefore closely connected with those of the aircraft industry. This policy had to be modified as a result of the rapidly deteriorating international situation, and Sweden was forced to buy more aircraft in Britain and may continue doing so for the time being.

No great changes are expected in the organization of the Air Force during 1951. Six of the ten day-fighter wings are being strengthened by 50 percent, and the Air Force hopes to obtain authority similarly to reinforce the remaining four. Depending on the availability of aircraft abroad, the Air Force also proposes to buy foreign night-fighter aircraft (probably de Havilland "Venoms"). By the end of 1951 most of the piston-engined fighters will have been replaced by jets, notably the SAAB J-29 fighter and attack aircraft, which during tests has exceeded its design top speed of 650 m.p.h. (and Mach .86) under full control.

Aviation Research

At a cost of Swed. Kr. 8,180,000 a large supersonic wind tunnel, permitting speeds between Mach 1.25 and Mach 4.00, is now being built and will be completed in mid-1952. In addition, a programme is under way for the modernization of Sweden's existing tunnels to provide better research facilities, particularly in the lower transonic speed ranges.

Late in 1950 the Swedish Aviation Research Committee proposed construction of two new tunnels at the Aeronautical Research Institute (FFA) near Stockholm at a cost of Kr. 27,700,000. One of them would be a continuous-flow tunnel, the second an ejector-type tunnel for intermittent operation for speeds around Mach 1.00. Both would be fed by air furnished from water tunnels 650 feet below the surface (a system used for the new jet engine laboratory at Svenska Flygmotor, Trollhättan). They could be ready in 1955-56 if Parliament approves the money. By that time the first Swedish supersonic fighter is expected to fly.

* Continued from INTERAVIA, REVIEW OF WORLD AVIATION, No. 2, 1951.

Oslo : Parliament.

Norway

Service Aviation

Oslo, February.—The development of the Norwegian Air Force is intimately connected with the activities of the other Atlantic Pact nations. A six-year Air Force expansion plan has been drawn up, and work has been started on it. It calls for eight day-fighter squadrons of 20 aircraft each and two night-fighter and light bomber squadrons. American transports (C-47s) have arrived under the arms aid programme. Deliveries of de Havilland "Vampires," Mk. 52, are continuing, and Norway will probably also get some Republic F-84E "Thunderjets" under the arms aid programme. The number of F-84E's to be delivered in 1951 is not expected to be very great, however, as only 300-400 have reportedly been allocated for European nations this year, of which Holland alone is to receive 100.

Existing fighter squadrons are at full combat strength. Emphasis is being placed on providing pilots and ground crews with a maximum of experience in winter operations with jets, for which purpose the many frozen lakes provide excellent landing fields.

Aircraft industry

Norway has a single aircraft workshop worth mentioning, Birger Honningstad's *Norsk Flyindustri*. Its latest product, the "Finnmark" twin-engined amphibian, which is particularly well-suited for work in the Arctic, has passed its final tests and is expected to receive its type-certificate in the summer. For the moment the company has no production plans.

Airports

Work is proceeding at the new combined military and civil airport at Hernes, near Bodo, in the North of Norway. The field, which is being built under the defence programme, will be ready in the spring of 1952 and will have the longest runways in Europe. Douglas DC-3s would use the field on domestic services, whilst domestic flying-boats would alight just north of Bodo.—The expansion of Oslo-Fornebu airport is also progressing.

Denmark

Service Aviation

Copenhagen, February.—The year 1951 will be one of expansion for the Danish Air Force. A thorough reorganization plan has been taken in hand, but the details of the new Air Force set-up under the Joint Defence Command are being kept strictly secret.

Sufficient funds have been allocated for the purchase of another six squadrons of 20 jet fighters each, in addition to the one already in existence. Furthermore, a number of F-84E "Thunderjets" are expected under the US military aid programme.

The first 25 air cadets trained in the USA arrived in Denmark in January. A considerable expansion of Danish flying-schools will be undertaken.

Switzerland

Berne, February.—The year 1950 saw steady development in military aviation in Switzerland and some reorganization in civil aviation.

Air Force and A/A Units

The Federal Military Department's estimates for the 1951-52 fiscal year, published in February, 1951, amount to the same total as in recent years, namely Fr. 470,000,000, to which must be added the first instalment of the Five Year Plan which provides for additional expenditure of Fr. 1,460,000,000.

Expenditure for aircraft procurement is included in the ordinary Air Force estimates of Fr. 56,000,000. The majority of this expenditure will doubtless go on the production under licence of 100 de Havilland "Vampire Mk. 6"; four private Swiss firms at Stans, Altenrhein, Schlieren and Grenchen are making the parts, which are then assembled by the Government factory at Emmen. The "Goblin" engines are being supplied direct by de Havillands. These 100 "Vampires" are to supplement 75 of these aircraft imported from Great Britain in 1949 and 1950. —Starting in 1952 the de Havilland "Venom" is also to be built under licence in Switzerland, as the "Vampire" will by then be obsolescent. "Ghost" jet engines for the "Venoms" will also be obtained direct from England.

Finally, American sources report that an all-Swiss jet fighter and engine are being developed at the Emmen works. Both engine and airframe are said to be of original design. As there is no reference whatsoever to such a project in the armament estimates, and since the difficulties of such an undertaking are not to be underestimated, these American reports should be viewed with caution.

The Swiss armament programme stresses the acquisition not only of tanks and anti-tank weapons, but also of heavy guns for the anti-aircraft defences and of radar equipment. The sum of Fr. 160,000,000 set aside for this purpose is also to cover the cost of underground constructions for the Air Force. Great importance is also attached to the import of rocket projectiles.

Copenhagen : Kristiansborg Castle.

Berne : Houses of Parliament.

Air Transportation

During 1950 Swissair, the national flag carrier, succeeded in extricating itself from the crisis caused by the devaluation of European currencies in 1949. Swissair had determined to pay its own way and to accept little or no subsidies from the Federal Government. But in Switzerland too the Government has had to lend a helping hand, although the Company remains in private ownership. It has received a government loan of Fr. 15,000,000 for the purchase of two Douglas DC-6 B's for the North Atlantic service, and a third aircraft of the same type is shortly to be added. The government is also taking over responsibility for depreciation and insurance of the Company's existing air fleet, so that the latter can gradually be renewed.

This grant of financial assistance was accompanied by personnel changes, in that Dr. Walter Berchtold of the Directorate General of the Swiss Federal Railways was appointed Director General of Swissair. His task, once he has familiarised himself with his new domain, is to strengthen the internal organization of the Company.

Many people, both in Switzerland and elsewhere will learn with regret that Dr. Rudolph Speich, President of the Swiss Bank Corporation, is to retire from the Presidency of Swissair in the summer of 1951. Dr. Speich has steered Swissair through difficult years and his immediate task may now be regarded as completed. Nevertheless the Company is losing a valuable asset and a man of outstanding abilities. It is to be hoped that his successor will carry on his good work.

Sporting Flying

The Swiss Aero Club, like every other Aero Club, is experiencing a post-war crisis, as far as sporting flying is concerned, owing to lack of funds. Marcel Devaud, the Geneva industrialist, who had been the Club's President for many years, retired in 1950, owing to pressure of other work. His successor is Dr. Muri, a well-known sports flyer and director of Philips Agency in Switzerland. Meanwhile a ray of light has appeared on the Swiss Aero Club's horizon. It is to assist in military training and undertake pre-military schooling under military supervision.

Germany

Bonn, February.—During 1950 there was still no such thing as German aviation, though there was aviation over Germany. The latter does not include the activity of the Occupation Air Forces, since this has existed since 1945, is at present, if anything, increasing and, unless the political situation changes radically, will doubtless continue for some time.

Bonn: The new West German Federal Parliament Building.

A short time ago when the possibilities of rearming Germany were being widely discussed, there were certain "Know-alls" who maintained that Germany was more likely to get a tactical air force rather than be allowed to operate commercial aviation (although the latter is so much easier to supervise). However, events have given the lie to this foolish supposition.

Today, with a revision of the Occupation Statute within sight, it is being openly stated that the West German Federal Republic will most probably be authorised to operate its own civilian air services this summer. And why not? Air services over Germany are at present being operated by about ten different foreign companies. They are by no means run to the satisfaction of air passengers and moreover this system drains the country of sorely-needed foreign currency. A first step in the right direction was taken in 1950 when the ground organization at German airports, or rather the ground services, were handed over to German management.

Pan American Airways' report that it carried approximately 105,000 passengers, 1,500,000 kg of freight and about 575,000 kg of mail on its German services alone during 1950, gives some indication of the demand for air services in Germany, in which nine other companies participate at present.

How is such German air transport to be organised? It is rumoured that a variety of offers has already been made, by the Scandinavians, Dutch, British, French and even by the Americans. It is also reported that the German partner in a new German company would be permitted to hold 51% of the capital. But these are merely speculations. Until the Federal Ministry of Transport has a Civil Aviation Department run by men who know their job nothing can be done towards the realisation of these plans.

The only other piece of news in connection with German aviation is the re-constitution of the Aero Club of Germany at the end of 1950. Its President is the universally popular flyer, Wolf Hirth, and its membership is already said to total over 30,000. But founding the Club and organising flying seem to be two very different stories. However, 1951 ought to see a resumption of German glider activities.

The Mind of Mr. Reader

Sir,

... I feel highly complimented at having been put on the same page as Esmeralda, the Stewardess ("Interavia," December, 1950). Whoever does those paragraphs which are attributed to her is remarkably clever. He or she gets off all kinds of little jabs and japes which could hardly be put into a serious article but are very effective as true words spoken in jest. In that way they remind me of the articles which used to appear in "The Aeroplane" in my time under the name of "Babs." They were written by an extraordinarily clever young woman named Constance Babington-Smith, who belonged to an unusually talented family. She joined the W.R.A.F. at the outbreak of war and somehow got on to the Photographic Identification Branch where she distinguished herself by being the first person to spot a flying bomb in a photograph of one of the launching sites in France. She was then sent to the United States to teach them how to "read" reconnaissance photographs. Soon after she arrived she had to face a press conference as she was not extremely popular because the US photographic identification people thought that they knew at least as much as she did. One press man asked her aggressively: "What did you come over here for?" Babs replied in her most innocent voice: "Because you sent for me." And after that she had it all her own way.—Esmeralda has just that innocent way of scoring off people.

... By the way, couldn't you start an agitation for the abolition of the word "defence"? Remember that "Defence is the first stage of Defeat." Call it protection of Western Europe, talk about protective air force or army, or about a deterrent to war, but do avoid the word defence, and if anybody uses it in an article put in a footnote that attack is the only certain form of defence...

New Malden, Surrey, England. C.G. GREY.

• Esmeralda says she is flattered at being compared with "Babs" Babington-Smith. She says she knows all about her from one of the Editors who met Babs in New York after the war when she was with the "Time-Life" organisation.—Esmeralda says she almost agrees with C. G.'s suggestion concerning the words "protection" and "defence," but she feels that in this non-aggressive period the term defence is quite useful because it does not force anybody to state what he really means... (Ed.)

Sir,

I wish to draw your attention to the illustration accompanying the Douglas DC-6A "Liftmaster" ("Interavia," November, 1950). The picture is that of a Douglas C-124 "Globemaster 2," not a DC-6 as intended.

Farnborough, Hants., England. B. J. SPICE.

• Reader Spice is more perspicacious than the Technical Editor, who spent a day in the doghouse for his oversight. The picture above shows a DC-6A "Liftmaster."

Sir,

I read with great interest Scholer Bangs' article in No. 1/1951 of "Interavia" Review on the terrific noise produced during American tests with afterburners for jet engines and test bench experiments on ramjet engines, and lastly on the complicated measures which have been taken to absorb this noise.

From my own fairly extensive experience of combustion in ramjets in flight and on the test bench I know that the total noise produced even by very large ramjets (up to 1.5 m = 4 ft. 9 in. in diameter) in the subsonic range does not rise above a not unpleasant humming or droning, provided the flow is kept continuous.

In "Schweizer Archiv für angewandte Wissenschaft und Technik" (Swiss Journal of the Applied Sciences and Engineering) No. 11 and 12, 1950, E. Sänger discussed the conditions frequently arising under which, owing to what is known as thermal obstruction, the flow of air in the presence of heat ceases to be continuous and begins to pulsate. This discontinuous adiabatic flow is indeed accompanied by harmful noise. However, this can as a rule be relatively easily overcome by reducing the critical Mach number of the air immediately before the beginning of combustion. The same of course applies to the afterburner for jet turbines, which fundamentally is nothing more than a ramjet behind a turbojet.

These facts seem to be relatively little known and I therefore thought that your readers would perhaps be interested in them, particularly in view of the tremendous cost of the anti-noise equipment described.

Courcell/Yvette (S.-O.) France. Dr. Irene BREDT.

Sir,

Your magazine "Interavia" is one of the most valuable on aviation. Articles appearing in it have been consistently interesting and illuminating and, if we may use the Service term, form "a real gen book..."

Air Headquarters, Indian Air Force, New Delhi. W/CDR. A. A. NARAYANAN Director of Intelligence.

Sir,

... I notice on page 633 (of the December 1950 issue of "Interavia"), where there is a photo of Northrop F-89 "Scorpion" fighters, that if you just glance at that picture quickly you will see that the resemblance between the "Scorpion" and the "Meteor N.F.11" is quite striking, despite the different engine position. It is not always appreciated that the geometry of the "Meteor" (10 years old in design) is still remarkably up-to-date. I think that if they had fitted a differently designed tail unit earlier, people would have been even more impressed. It is still a very good aeroplane, and it gives very little trouble in the compressibility region, and I should imagine that the new night fighter version, with its even longer nose than the Mark 7 two-seater trainer version, should be very well behaved. If this is the case, the type may well be faster at altitude than the earlier marks, since there is quite a bit of power in hand when the machine reaches its limiting Mach number of .83.

The technical article by Gollob ("Is the Propeller-Driven Fighter Obsolete?") poses a very interesting problem, but one which can only be solved in practice. I wish we could see the "Vampire" on active service. It is surprising that the Australians have ordered the "Meteor" for use in Korea when they are, as far as I know, now delivering "Vampires" from their own factories.

London. J. H. STEVENS.

• For comparison: Left, the F-89 "Scorpion"; right, the "Meteor N.F.11" night fighter.

H-5 Rotor Anti-Icing System

By E. J. KATZENBERGER, Bridgeport, Connecticut

The writer, who today is Chief Design Engineer of the Sikorsky Aircraft Division of the United Aircraft Corporation, was born in New York City in 1916. He studied mechanical engineering at New York University and joined Sikorsky's in 1942. He designed the XR-5 helicopter (now known as the H-5) and became Chief Design Engineer in 1949. E. J. Katzenberger is a member of the Institute of the Aeronautical Sciences and has been President (and Vice-President) of the American Helicopter Society.

It has been recognized for some time that all-weather operation of helicopters cannot be expected in the absence of an effective rotor blade anti-icing or de-icing system. While the service use of helicopters has not been extensive enough for the accumulation of icing data of much significance, icing has occurred and under certain conditions can be expected to be much more severe than that thus far encountered.

Experience with propeller icing in fixed-wing aircraft has provided evidence enough of the possible danger, and as early as 1942 the Air Materiel Command endeavoured to anticipate the problem by contracting with Princeton University for the investigation of rotor icing and the means for its control. Towards the end of World War II, icing tests of an R-4 helicopter at the summit of Whiteface Mountain, in the State of New York, conclusively demonstrated that, at least for the conditions obtaining during the tests, dangerous accumulations of ice can be encountered on rotor blades. War problems of higher priority, however, prevented adequate exploitation of the results of these investigations and, while valuable research techniques had been developed, neither a practical ice control system nor sufficient generalized information for the determination of the parameters of such a system for design purposes had been achieved.

The status of the problem remained substantially unaltered until the summer of 1949, when the Air Materiel Command contracted with the Sikorsky Division of United Aircraft Corporation for the development of an ice control system for the H-5 helicopter. The problem had become urgent since large numbers of H-5 helicopters and its variants had by this time been placed in service throughout the world. The immediate objective was, therefore, to develop a practical ice control system for this aircraft. The long-term objective was to develop methods of analysis by means of which the required parameters for the ice control system of any helicopter could be worked out with a reasonable degree of certainty.

*

The problem had been anticipated during the design of the Sikorsky all-metal rotor blade several years previously. The leading edge of the blade, which is also the blade spar, is a single-piece aluminium alloy extrusion. Chordwise ribs are not employed in the leading edge, so that a duct is formed, continuous from root to tip, ideally suited for conducting a continuous flow of heated air from a source at the root of the blade to an exit at the tip. The blade retention is so designed that access to the root end of the duct is not obstructed by the blade retention.

Modification of the blade for an anti-icing installation is therefore exceedingly simple, consisting only of the insertion of an insulated entry at the root and the provision of a tip exit which is simply a rectangular orifice cut in the tip fairing. These blades are standard production equipment. The modifications affect neither their balance nor their structural integrity. Thus, since the blades are by far the costliest component involved in the anti-icing system, the fact that conversion to anti-icing required so negligible a modification immediately established the necessary condition for the primary objective; namely, that modifications to service aircraft, if the installation of anti-icing equipment became necessary, should be neither extensive nor costly.

This fact formed the point of departure for the design of an ice control system for the H-5 helicopter. The most probably fruitful course, from the practical standpoint of the particular problem presented, was clearly to investigate the possibilities of hot air de-icing or anti-icing. The Sikorsky engineers were not confronted with a wide research programme, but with the specific problem of ice on the blades of a particular helicopter. It was evident that these blades were most readily adaptable to the hot-air method of ice control.

It should be noted that parallel concurrent studies of alternative methods were not made and that, therefore, no comparative theoretical assessment of alternatives attempted before proceeding with the hot air system. This procedure was considered to be justified, however theoretically inconclusive the evidence in favour of a hot air system, for the following reasons, aside from the practical attractiveness as noted above:

(a) The scope of the programme was severely limited as to time and funds available; hence, experimentation with more than one type of system could only be justified if the type chosen was found to be demonstrably impracticable.

(b) The difficulties of adequate theoretical treatment of certain problems in alternative systems—as, for instance, the optimum arrangement of electrical conductors in a blade leading edge, or the efficacy of an oil film—were excessive; hence, analytical comparisons could be expected to be lengthy and inconclusive.

(c) The previous work accomplished by Princeton University, while inconclusive, appeared to indicate that electrical power requirements would be of the order of 60 to 70 horsepower. Electrical equipment for the generation of power of this order is several times heavier than the equipment required for the equivalent hot air system.

(d) Experimentation by Princeton University with oil films had been uniformly discouraging.

(e) The most successful systems currently in use are hot air anti-icing systems, and considerably more information is available as to the characteristics of such systems, methods employed for analysis, available equipment and solution of detail design problems than similar information on alternative systems.

(f) The hot air system possesses a practical advantage, from the standpoint of the overall design of the aircraft, in that the same equipment is employed alternatively for cabin heating in extreme low temperature conditions where heat for anti-icing is not required. The helicopter, it should be noted, operates well below the altitudes at which extreme low temperature icing is experienced.

*

The first step in the design of the system was the determination of the required heat quantity and flow rate of heating air. The method of analysis employed was a straightforward application to the rotor blade of methods of airfoil heat-transfer analysis developed by the NACA and the Air Materiel Command. Briefly, the aerodynamic conditions at the airfoil are established and the local surface heat transfer coefficients are determined for the leading edge, the laminar flow region forward of the transition point and the turbulent region aft, using relations developed by the above sources in which

the heat transfer coefficients are functions of the absolute temperature of air and airfoil surface, free stream velocity, the airfoil configuration, air density, and distance along the profile of the point investigated from the stagnation point. Since the aerodynamic conditions vary along the blade from the root to the tip, a step-by-step analysis was made at increments of ten percent of the blade radius.

The primary factors involved in the heated air system are :

(a) Quantity of air flow

(b) Blade and duct dimensions

(c) Ambient temperature and pressure

(d) Temperature of the air entering the blade.

The temperature of the air entering the blade is limited by the capacity of the spar material to retain its physical properties at elevated temperatures. Data as to the effect of elevated temperatures on the static strength of the aluminium alloy spar material indicated that 300° F. (148° C.) should not be exceeded.

In passing through the blade the heated air loses some of its internal heat to the blade spar by convective conduction. The spar in turn loses heat in a similar manner to the atmosphere. The heat lost to the spar is equated to the heat lost from the spar.

The internal and external heat transfer coefficients at any section are calculated, using methods of heat transfer analysis developed by the NACA and AMC as indicated above. The heat-balance equation is then used to determine the surface temperature at any section and the analysis carried out for each of the sections at ten percent increments of blade radius.

The analysis was originally carried out for dry air and it was on the basis of this analysis that the heat-source equipment was chosen. Blade surface temperatures measured in flight were checked against temperatures predicted by the method described above for the atmospheric and blade-loading conditions obtaining during flight test. Good agreement was found throughout the range of conditions tested.

Later an investigation was made of the performance of the system under specific icing conditions. The relevant meteorological factors are : [1]

(a) Water content of the atmosphere

(b) Droplet size

(c) Temperature

(d) Altitude.

Although the scope of the programme did not include tests under actual icing conditions, these conditions were investigated analytically since the dry air predicated performance will be considerably affected by surface wetting and evaporation.

The phenomena existing under icing conditions may be summarized as follows : When icing conditions are present in the atmosphere, some of the moisture that impinges on the blade surface can be expected to evaporate if the surface temperature is above ambient temperature. The evaporation rate is dependent on the surface temperature which in turn is partially affected by the evaporation rate. When all of the impinging moisture is not evaporated at the leading edge area of impingement, the problem of runback is encountered. A portion of the unevaporated moisture will run back over the colder trailing edge. The remainder will blow off into the air stream. The runback portion will form ice if the trailing edge surface temperature is below the freezing temperature.

For the all-aluminium type of blade construction employed in the H-5 helicopter, in which excellent chordwise heat conduction is obtained, the most efficient anti-icing system will not evaporate all the impinging moisture but will evaporate only a portion and maintain trailing-edge temperature just sufficiently high to prevent freezing of the liquid runback. The efficiency of the H-5 system, expressed as the ratio of heat lost in heating the blades plus heat lost at the tip to the heat available at the heater, is approximately 65 per cent.

*

The H-5 ice control installation consisted of the following :

(a) A source of heated air.

(b) Ducting from the source of heated air to the rotary collector at the rotor hub.

(c) A rotary collector to transfer the heated air to the rotating blades.

(d) Controls for varying heat supplied.

(e) A fan for varying the flow rate of heated air.

(f) A metering tube and orifice for measuring air flow.

(g) Pressure and temperature indicating and recording equipment.

Assessment of the relative merits of exhaust heat-exchangers and independent combustion heaters was made before choosing a source of heated air. An independent combustion heater was chosen since it provided greater flexibility for test purposes, was very much cheaper, more readily available, and its characteristics were known with a greater degree of certainty than those of a specially designed heat-exchanger. The preliminary calculations indicated that the heat requirements were approximately 125,000 BTU/hr (31,500 kcal/hr) with an air flow rate of approximately 1700 lb/hr (770 kg/hr). The capacities chosen for the test equipment were 200,000 BTU/hr (50,400 kcal/hr) and 2000 lbs/hr (910 kg/hr) with a temperature *rise* of approximately 200° F. (110° C.) above ambient to be made available at the blade duct entry. Means were provided for varying the heat flow from 90,000 BTU/hr to 180,000 BTU/hr. To relieve the pilot of excessive manipulation of heater controls, an automatic fuel-air regulator was incorporated in the system.

The complete heater installation, together with combustion and heated air fans, was constructed as a single bench assembly and bolted externally to the left-hand side of the cabin. Thus, the installation was completely accessible for adjustment and could be quickly removed for modifications in the shop. An actual installation would, of course, be internal.

The duct from the heater to the rotary collector was a conventional wire and fabric duct with asbestos and fiberglas lagging. Like the heater, it was completely external for reasons of convenience. Considerably less weight of lagging would obviously be required in an internal installation.

The rotary collector was in the form of a ring of rectangular cross-section supported on the swashplate assembly. The lower, stationary component of the collector was supported on the non-rotating portion of the swashplate assembly and formed three sides of the rectangular cross-section. It was spun from a single sheet of aluminium alloy. The upper, rotating component of the collector was supported on the rotary portion of the swashplate assembly and formed the upper side of the rectangular section, being simply a heavy plate of aluminium alloy. Mounted on the upper face of the stationary component of the collector were circular segments of graphite at the inner and outer diameters of the collector, matching the polished lower face of the rotary component, thus forming a seal at the inner and outer diameters. The rotary plate was forced down upon the graphite seal by means of springs, at a contact pressure of ½ psi. (0.035 kg/cm²). Three flanged holes in the rotary plate provided attachment for the flexible ducts to each of the three blades. The complete assembly was thoroughly lagged with asbestos sheet.

Chordwise, spanwise, and heated air temperature measurements were made on the blades by means of thermocouples and recorded on automatic recording equipment installed in the baggage compartment. Current was transmitted through the rotor hub by means of slip rings installed in the swashplate assembly.

During flight and ground tests the flow of heated air was the primary variable, a rheostat being employed to control the speed of the heated air fan. The heated air exit temperature was held at a substantially constant value, the fuel-air ratio being automatically maintained approximately constant by a diaphragm type regulator located in the fuel supply line. The combustion air flow rate was manually controlled in similar fashion to the heated air flow rate.

Operating procedure was to observe and record data at one set of flow conditions. Different sets of conditions were obtained by changing the heated air fan speed, thus changing the flow of air through the heater. Since it is then necessary to burn a different quantity of fuel to keep the heater exit air temperature constant, the operator then readjusts the combustion air fan speed while observing the exit air temperature. He is relieved of the necessity of readjusting the fuel flow rate by the automatic fuel-air regulator. Approximately ten flight hours were accumulated during test.

*

It has already been observed that good agreement was reached between predicted dry air performance and flight test results. Flight or ground tests under controlled icing conditions are clearly indicated as the immediate course of further investigation. Despite the unavoidable limitations to the scope of the programme, however, the primary objective has been in large part attained in that a practical basis for a service-worthy ice-control installation has been achieved.

* * *

[1] Cf. INTERAVIA, Review of World Aviation, No. 12, Vol 5, pp. 644-646. — Ed.

En Route Navigation Systems and Air Traffic Control

By Tankred von HAUTEVILLE, Stuttgart.

The author, Dipl. Ing. Tankred von Hauteville, was born at Liegnitz in 1908 and studied telecommunications and high frequency techniques at Stuttgart Polytechnic. After working for several years at the Deutsche Versuchsanstalt für Luftfahrt (German Aeronautical Research Establishment) at Berlin-Adlershof, he obtained his pilot's certificate for multi-engined aircraft (C2). From 1934 to 1945 he was head of the Radio and Navigation Section of the Luftwaffe's Rechlin Test Centre and during the war supervised all Luftwaffe radio test centres. — Since 1948 he has been working as development engineer for the firm of C. Lorenz AG., Stuttgart.

Regular and reliable operation of air transport regardless of weather conditions is essential if full return is to be obtained on the capital invested in aircraft, aerodromes and other allied equipment.

Modern multi-engined aircraft are already to a large extent equipped for all-weather flying, and the number of aerodromes which are big enough to permit of bad weather take-offs and landings by large aircraft is increasing from year to year. The increasing density of flight in bad visibility makes air traffic control particularly important. Like other forms of transport, air traffic tends to concentrate in heavily populated areas. In Western Europe the triangle London-Brussels-Paris forms a region of particularly heavy air traffic, with its main centre in the London area.

It is recognised that the capacity of the landing runway is the real bottle-neck in air traffic. Consequently the landing time-table becomes the determining factor for the whole of the flight plan, from the point of view of both time and space. An increase in density in the landing time table and the regular, reliable operation of the latter cannot however be achieved by purely local measures or merely by equipping the aerodrome with the most complete and modern landing aids. On the contrary, to achieve this degree of density and reliability it is essential that there should be, within a radius of at least 125 miles of the aerodrome and if possible along the whole route from take-off to landing aerodrome, navigation aids and equipment which enable the aircraft to keep accurately to and constantly check its general flight timetable and route plan. When the checking of the flight timetable and the execution of its basic route plan takes place on board the aircraft it is known as navigation, and when the checking is done on the ground, as air traffic control (ATC).

Relationships between navigation and air traffic control

The scope of navigation and air traffic control overlap more and more as traffic density increases, so that any examination of modern radio navigation systems must concern itself not only with their actual value from the navigation and flying points of view, but also with the extent to which they are adapted to the requirements of ATC.

This applies in particular to navigation systems which are used now and are to be used in the future for actual route traffic in areas of dense traffic, e.g. Western and Central Europe.

The following remarks apply primarily to these short-distance aids to air navigation.

The degree of accuracy required of a radio navigation system in regions where the air traffic control fixes the flight timetables is largely determined, not only in the neighbourhood of the aerodrome of landing, but also along the route, by the requirements of air traffic control. For example in 1946 the Special Radio Technical Division (COT) of PICAO gave the following definition of the accuracy requirements: "The operational accuracy of the system shall be such that the pilot of an aircraft may, in normal conditions, make good an Estimated Time of Arrival at a desired point within plus or minus thirty seconds after having calculated that ETA from a point fifty miles distant".

Another important point in connection with the evaluation of navigation systems in their relationship to the requirements of air traffic control should be mentioned here. The increasing speeds of flight mean that any delay in interpreting navigation values in the aircraft or position reports on the ground has virtually the same effect as a navigation error due to insufficient accuracy of the system itself. Space and time are closely interrelated.

Because the landing timetable is of primary importance in the general flight plan the following point must be stressed. The shortest flight path—to fly this was the original "classic navigation problem"—does not necessarily mean that the flight will be carried out in the shortest possible time. Only if the route timetable is so fixed —and maintained— that the landing approach can be made without waiting will the shortest flight path coincide with flight in the shortest time, the principal objective of all modern highspeed traffic.

The greater the density of traffic the higher will be the air traffic control's demands on the efficiency of the navigation system. The less the landing timetable affects the route plan the more important becomes the classic navigation problem of flying on a direct course, e.g. in long-range traffic.

Requirements in the aircraft

In the simplest case all that is required on board is to receive an indication of what course must be steered to get by the shortest way from the present position to the destination aerodrome. In such cases it suffices for the bearing of the aircraft in relation to this aerodrome to be known on board.

If this course is to be flown as a lane, an instrument is required which will enable the desired base line to be set as required value, and an indicator to show deviations. Here it is immaterial in principle how these deviations are indicated (rate or displacement). The only important point is that the indication of deviation should be sufficiently sensitive and that it should be possible to steer direct from it. Direct coupling to the automatic pilot so as to relieve the pilot is greatly

desirable and this possibility should not be overlooked in judging a system.

Knowledge of present position is not important if it is merely a question of steering the course which will give the shortest flight path. There is a difference of opinion as to whether this simplest of all methods of using radio aids should be called " radio navigation ". However, it must be admitted that untold millions of miles have already been flown by this method and will be flown in future. For decades all " en route navigation " in Europe consisted of a few *QTE* or *QDR* bearings after the take-off and then as many *QDM* bearings from the aerodrome of destination as possible, whilst in the USA on the main routes, aircraft have always flown on lanes which were marked by beams (radio ranges). Thus it is obvious and readily understandable that aircraft crews should demand that any new en route navigation systems introduced should permit this convenient and well-tried method of using radio aids to be continued, at any rate as a kind of " basic method ".

It is of secondary importance for the pilot to know his exact position. Such knowledge is not essential in the above-mentioned system. Knowledge of position is only required when a change in course has to be made to avoid obstructions or prohibited areas, and above all when space-time calculations have to be made. These calculations provide the ground speed, wind velocity, wind direction and the estimated time of arrival (ETA), i.e. the values which enable the route flight plan to be checked and which are essential if the transition from route timetable to landing timetable is to be made without waiting. As the ETA is the most important value here, knowledge of the distance from present position to aerodrome of destination is of primary importance—the change in this distance per unit of time gives directly the ground speed, which is essential to the calculation of the ETA.

Such were the requirements laid down by the Special Radio Technical Division (COT) of PICAO in 1946 for short distance navigational aids. In essence they are : the presentation of information " in convenient and natural form " and " in a manner directly applicable to the handling of the aircraft ", and the provision of " continuous visual indication of distance and azimuth on any track within the coverage area of the system ".

To sum up, an aircrew's primary demand on a navigation system is " flyability ", by which is meant above all simplicity, speed and accuracy of conversion of the instrument values into " flyable values ".

Ability to provide positive immediate indication of failure or improper functioning (which is largely affected by the frequency range of the system), reliable range, transmission of the course impulse to the automatic pilot and last but not least low weight of air-borne equipment complete the list of requirements.

Fig. 1 : Normal version of a VOR-Omni-range ground installation. The aerial comprises five loops protected by a large plastic casing.

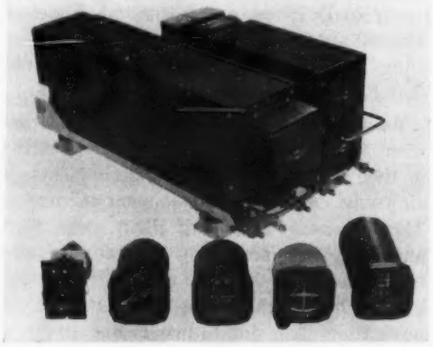
Ground requirements

On the ground the main requirement is not " flyability " but " adaptability to air traffic control purposes ".

Starting with the landing timetable to ensure maximum utilisation of the landing runways, the air traffic control draws up a general flight plan and checks that this is kept to or adapts it to traffic requirements. Expeditious and unhampered traffic flow and maximum safety are naturally of primary importance. The best possible utilisation of airspace and landing runways, without danger of collision in the air or on the ground, must be ensured.

To carry out this task the air traffic control ground station requires : (1) plan position information accurate in time and space and as complete as possible—" where are there aircraft ? " and (2) knowledge of the identity of the aircraft at a given spot—" Who is the aircraft ? ". The latter question and the whole question of communications will not be dealt with here. Identification and communications are among air traffic control's most difficult problems.

Fig. 2 : Collins VOR navigation receiver (type 51 R-1) with various indicators which can be used as required.



There are two basic methods of obtaining plan position information :— (1) it may be provided direct from special search equipment (primary or secondary radar) on the ground, or (2) the position fixes obtained on board the aircraft from its radio navigation equipment may be transmitted to the air traffic control as position reports. Constant automatic transmission of these values must be ensured, at any rate in the future, with the minimum effort on the part of the crew.

This is not the place to examine the pros and cons of these two systems ; suffice it to say that for a long time to come the second system will continue to exist alongside the first. Thus it follows that air traffic control must make direct demands on the navigation systems for airline flying, the chief being that position reports for the general picture of the situation should be transmitted in suitable form, rapidly and reliably, with sufficient accuracy, at adequate intervals and without delays.

This adaptability to air traffic control requirements, however, must not affect the aircrew's demand that the navigation system should be such that all air traffic control instructions can be carried out simply, without confusion, with sufficient accuracy and without delay. Only thus can the flight plan be carried through correctly in time and space.

From what has already been said it is clearly unnecessary to give any consideration to systems of ground direction finding as they fall short of practically all modern requirements, particularly as regards air traffic control.

Beam navigation systems

The first aircraft navigation systems to be put into operation on any scale were the beam systems. In Europe they were used to an increasing extent from 1933 onwards, particularly for bad weather landing approach, i.e. for pure close-range navigation (Lorenz VHF landing radio beacon, Standard Beam Approach).

For landing approach the beam system —in the form of the VHF/UHF Instrument Landing System (ILS or SCS 51) is today the ICAO standard. For en route navigation too the beam system has been largely used, especially in the USA, in the form of LF radio ranges. Since 1945 there has also been an increasing number of radio ranges in Western Europe. In the Berlin airlift, for example, they formed the backbone of the flight safeguarding system.

These LF radio ranges, like the visual-aural ranges, need not be discussed in further detail here. The former are out-of-date, because of their many shortcomings, and the latter, in spite of their improved qualities, can be regarded only as a provisional solu-

tion. In the USA the visual-aural ranges are already being progressively replaced by omni-directional ranges; in European air traffic they play only a subordinate rôle.

VHF Visual Omni-directional ranges

Rotating beacons, unlike the above-mentioned 2 and 4-course beacons, transmit direct course signals in all directions, i. e. throughout 360° and thus to a large extent satisfy the demands made today both in the air and on the ground of a navigation system (fig. 1).

The Visual Omni-Range (VOR) belongs to the class of rapidly-rotating phase-measuring radio beacons and produces in the aircraft a continuous reading of the angle between the magnetic north of the ground station and the line connecting the aircraft's position to the ground station. This article does not propose to go into the technical details of ground or airborne equipment, but will restrict itself to a consideration of the cockpit dials.[1]

VOR cockpit dials

A number of different instruments have been developed to provide VOR readings (figs. 2 and 3). The *course selector*, also known as the radial selector, azimuth selector or omni-bearing selector, has a 360° scale which can be set by hand to any desired course from or to the ground station. Its sense indicator is a two-position indicator which shows whether the course set is " TO " or " FROM " the ground station.

The *course deviation indicator*, a zero instrument, which is identical with the cross-pointer in the Instrument Landing System, shows whether the aircraft's actual bearing coincides with the desired bearing set on the course selector. If the vertical needle points to zero the two values are identical.

[1] A detailed description of the omni-range system and equipment will appear in a later issue of INTERAVIA, Review of World Aviation. — Editors.

Fig. 3 : The most important indicators used for VOR navigation. Top right, *the Radial (or course) Selector, shown with its sense indicator.* Top left, *the Course Deviation Indicator (also ILS cross-pointer), which indicates deviations from the bearing set on the radial selector.* Bottom left, *the radio magnetic indicator with two needles : the main needle always shows the QDM direction to the selected VOR ground station ; the triangular marker shows the actual heading or direction of the aircraft's longitudinal axis (magnetic wind course, here zero degrees).* Bottom right, *another auxiliary instrument (omni-bearing convertor).*

All these readings are independent of the aircraft's heading, and correspond to the *QDM* or *QDR* bearings in the ground D/F system. The *radio magnetic indicator* (RMI) differs from the course selector in that its scale is controlled from a Gyrosyn compass, so that the aircraft's magnetic heading is indicated by the triangular marker on the rim of the instrument. The needle of the RMI dial points on this scale direct to the ground station and so enables the relative bearing to be read off. The Radio Magnetic Indicator is identical with the indicator for the automatic radio compass such as is used in conjunction with long-wave D/F equipment. If the aircraft is so steered that the VOR needle points to zero, the deviation indicator will also show zero and the aircraft's longitudinal axis will be pointing to the VOR ground station.

The RMI can also have a second needle, which may, if desired, be connected to an automatic D/F equipment or a second VOR receiving equipment.

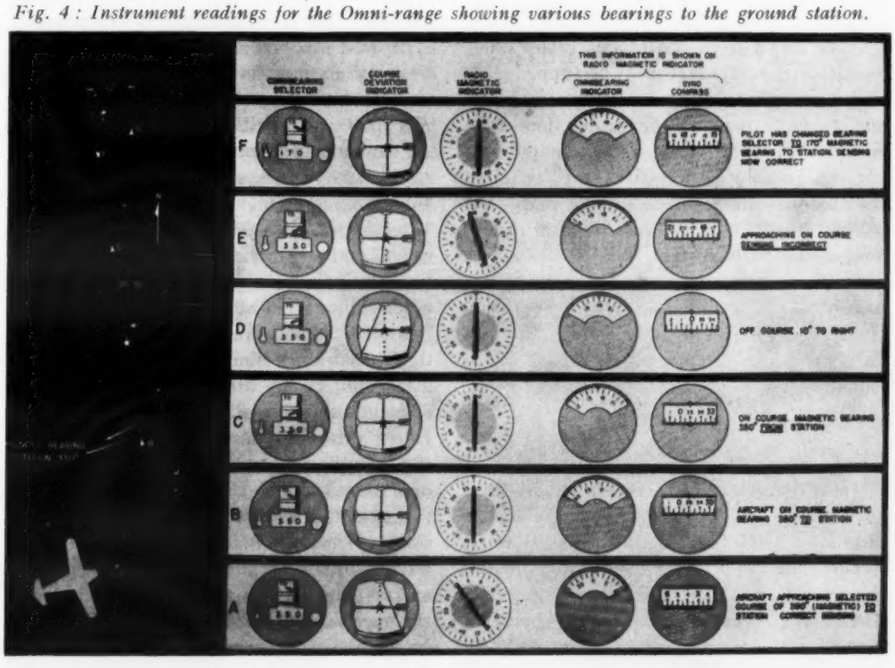
The various instrument readings for a flight track with varying course and bearings are shown in fig. 4.

It is therefore seen that the Visual Omni-Range enables the pilot to fly directly from the instrument readings, without further calculations. Thus the condition of " flyability " is largely met. To determine position by the pure omni-range system a second VOR is of course required (intersection of the two base lines on the map).

The American plans for the extension of short-distance aids to air navigation provide for the supplementation of the visual omni-ranges by replier beacons which will enable the distance of the aircraft from the ground station to be continuously measured and indicated on board (Distance Measuring Equipment=DME). The necessary airborne equipment is shown in fig. 5. This is a system of *polar co-ordinate navigation*, also known as Rho-Theta (R/Θ) navigation, which satisfies the requirement for constant azimuth and distance readings, i.e. position indication, and enables speed in relation to the ground to be determined in very simple fashion without map work. The range of the omni-range beacons is approximately equal to optical range and they are normally set up at intervals of about 100 miles, corresponding to their range at an altitude of 4,800 ft. The projected VOR network for Western Germany is shown in fig. 6.

A large number of systematic investigations have been made in the USA into the accuracy of angle measurements, their dependence on location and terrain and other propagation conditions, to check how far the VOR system satisfies the ICAO requirement of an accuracy of $\pm$ 2° for all angles of elevation from 0 to 40 degrees. It would appear that this requirement can be met, as the CAA accepts only ground stations that fulfil these conditions. The

Fig. 4 : Instrument readings for the Omni-range showing various bearings to the ground station.



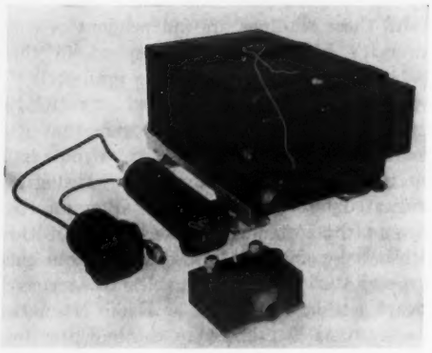


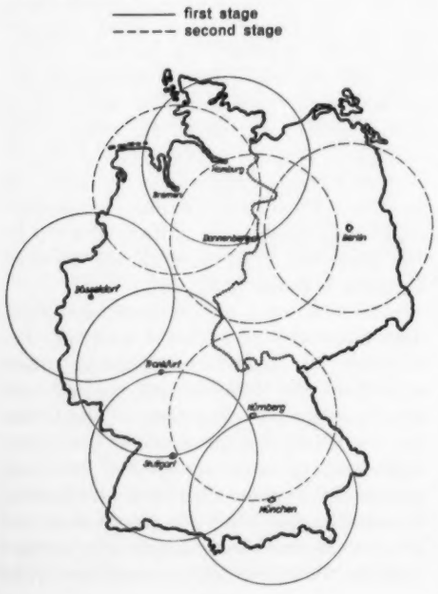
Fig. 5 : The DME equipment used by the USAF works to an accuracy of ± 0.2 nautical miles. It weighs only 44 lbs. This equipment requires a DME repeater beacon near the VOR station.

stricter requirements of the RTCA plan, which ultimately will permit a bearing error of only ± 0.6°, have not yet been met.

However, until position fixes are transmitted automatically from the aircraft and appear automatically in the air traffic control's plan position indicator, i.e. until all delay in transmission is eliminated, present-day errors will not greatly increase the total error.

A decisive advantage of polar co-ordinate navigation, in its hitherto most successful form of a combination of omni-range and DME, is that all the ground equipment so far proven in practical operation, i.e. primary and secondary radar, provide their readings direct in polar co-ordinates. The combination of omni-range and DME fulfils the requirement that a navigation system be adapted to the needs of air traffic control, at the same time requiring the minimum effort for the comparison of the position reports obtained by the various systems.

Fig. 6 : Projected Omni-range network for Western Germany.



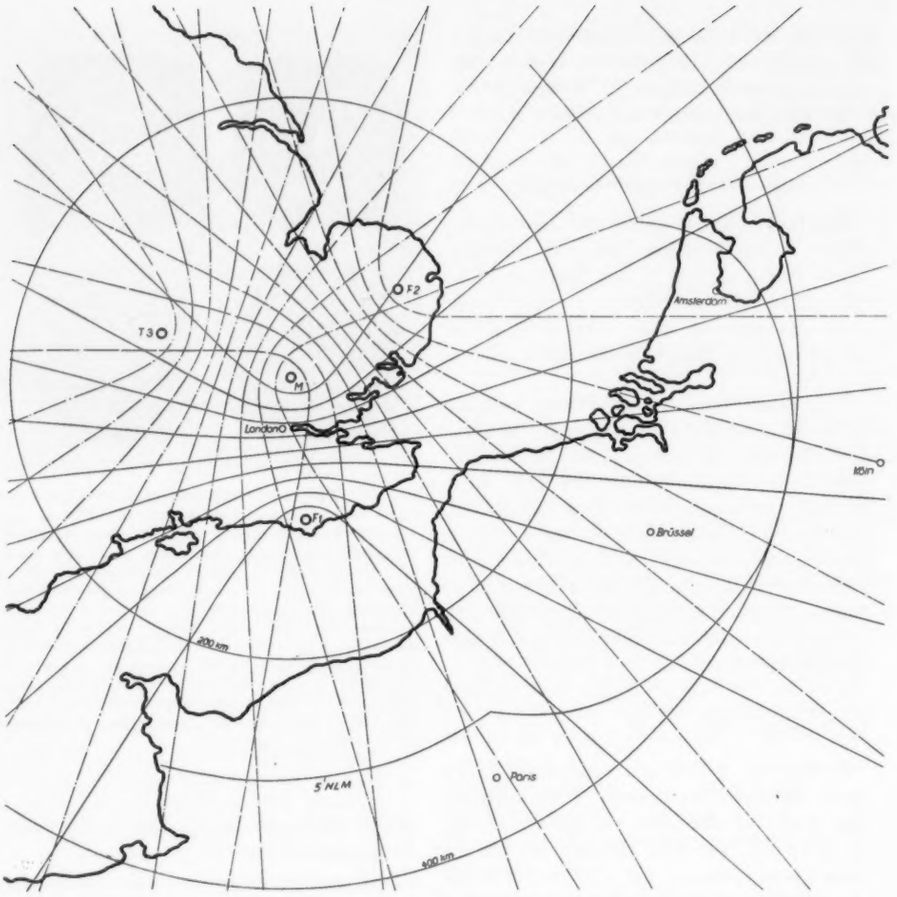


Fig. 7 : Decca map of Northwest Europe showing circle for position fixing to within 5 nautical miles accuracy (night range).

Air traffic control requirements are adequately met in areas where traffic is not too dense and where it is sufficient to stagger arriving and departing aircraft in height on direct courses. If in the polar co-ordinate navigation system any desired offset course is to be flown from continuous dial values, the airborne equipment must be supplemented by an offset course computer, which is said to have reached the production stage in the USA. The offset course computer is not an absolute necessity—the required calculations can be made on the map—but it does greatly increase the universal usefulness of the VOR system.

Another advantage of the omni-range beacon is that messages, such as general traffic instructions, weather reports etc. can be sent on its frequency channel without endangering the navigational functions.

Hyperbolic navigation systems

These include all those radio navigation systems in which the navigational co-ordinates are obtained from a family of hyperbolic " radio lines " produced by two or more transmitters working together. These hyperbolas are defined as the geometric locus for the reception of signals with the same difference in travel time or phase. As it is technically possible to measure time or phase differences with a high degree of accuracy and also to produce readily measurable phase differences for small linear differences in position, even over long distances (though at the expense of clarity of readings), hyperbolic systems are popular where a high degree of accuracy is required. Such systems were developed in particular during World War II by the British, the Americans and the Germans in a number of variations working in different frequency bands. The phase difference systems include the English " Decca " and the German " Erika " system, whereas the American " Loran " and the English " Gee " systems are examples of time difference (impulse) systems. The " Gee " system acquired the greatest practical importance since it was accurate and little subject to atmospheric interference, although these qualities were to a certain extent offset by the cumbersome nature of the equipment and certain difficulties of operation. After the War attempts were made by the British to have the " Gee " system recognised as a standard en route navigation aid, at any rate in the European and Mediterranean region, particularly as the necessary ground stations already existed in the British Isles and part of Western Europe.

This proposal, however, was not put into effect, since the airborne equipment was too bulky and too difficult to operate, and its accuracy and freedom from interference do not balance the poor " flyability " of hyperbolic systems in civil flying. Moreover the effect of the USA's unambiguous decision in favour of polar co-ordinate navigation should not be overlooked in this connection.

In recent years development of the Decca system has been continued with special reference to its use in air navigation. Being highly accurate and of long range, it merits serious consideration in connection with the organization of en route navigation aids in Europe. Unlike " Gee " however, " Decca " has not yet been used to any appreciable extent in either civil or military aviation in England, its country of origin. It is used (about 1000 sets) for shipping, for which the conditions of long-wave propagation are particularly favourable. So far there is one Decca chain in England and one in Jutland for the North Sea and adjacent waters, and two more chains are under construction. It is not possible, however, to draw any very certain conclusions as to its suitability for air navigation from its use in sea navigation.

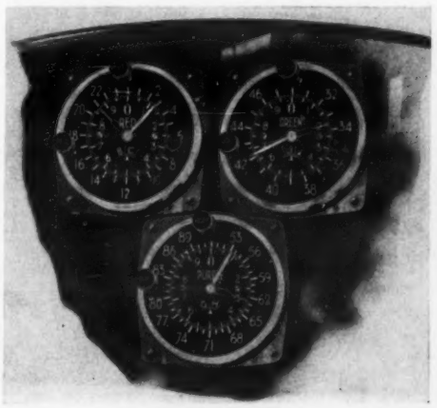
A Decca chain consists of a system of four long-wave transmitters. A master station and three slave stations are erected at a distance of about 60 miles from one another. These emit phase synchronised signals on frequencies between 70 and 130 kc/s. To determine position two families of hyperbolas, formed by the master and two slaves, suffice. The Decca system however uses a master and three slaves to produce three families of curves so that there will be favourable angles of intersection between the hyperbolas over the widest possible area and in all directions (cf. fig. 7). The accuracy of position fixing depends on the angle of intersection of the hyperbolas, which becomes flatter and flatter as distance from the chain increases, unlike the angles of intersection in the polar co-ordinate system, in which the radio base line (Rho) and distance measuring circle (Theta) in principle always intersect at right angles. Furthermore a distinction must be made in the Decca system between the day range and the reliable night range. The space radiation occurring at night, even at the low operational frequencies used, reduces reliable night range to between 180 and 250 miles, as compared with over 620 miles by day.

Certain conflicting values have been published for the accuracy of the Decca system. Nevertheless a precision of 0.02° (for 50 % of all measurements) is said to be attained night and day up to a distance of 160 miles. By day and in the absence of space radiation this degree of measuring accuracy is maintained for distances of over 320 miles. At night accuracy at 180-250 miles, according to direction, is not less than 1.5°, even in unfavourable conditions. The accuracy of the Decca system within the region of purely ground wave radiation is considerably greater than that of the VOR, and with its orientation error of approx. 100 yds. in 60 miles it even exceeds the requirements of the RTCA plan. The question, however, arises of whether full advantage can be taken in civil aviation of auch extreme precision.

Any plan for providing a region with Decca chains must be based on the reliable night range. It must also be borne in mind that during the months of bad weather long-wave stations generally provide pure ground wave radiation only for a few hours a day (round about midday). Thus for an area 180 miles square four ground stations are required, the same as for the VOR system.

Let us now consider the " flyability " of the hyperbolic systems. Apart from the central perpendicular joining master and slaves, the radio lines produced by the system, known as lanes in the Decca system, are not straight lines which coincide with a great circle of the earth, but hyperbolas which cannot be flown without constant changes of course. The hyperbola passing through the destination is nowhere in space the shortest connecting line. Three " Deccometers " (fig. 8) in the aircraft indicate which lanes of the three families of hyperbolas, which are numbered, correspond to the aircraft's position at any given moment. Since it was found in practice that readings were frequently ambiguous, a fourth instrument known as the Lane Identification Meter, was added. Thus in the hyperbolic systems neither direct courses to destination nor base line can be flown from the actual radio navigation readings. This requirement, defined earlier as a " basic requirement ", is therefore not met, nor is the demand that the system be directly connected to the automatic pilot, which is such an advantage in the VOR system. The direct indication of distance, such as is provided by DME is also not possible in hyperbolic systems.

Fig. 8 : The three " Deccometers " give the numbers of the hyperbolas of the red, green and purple lanes, whose point of intersection marks the position of the aircraft.



If distance values are required in hyperbolic navigation, they must be calculated from the position fix (intersection of two hyperbolas on the map), a distinctly more cumbersome procedure than the direct distance indication in DME. The " flyability " condition—according to our definition —is thus not fulfilled in hyperbolic systems.

To eliminate this shortcoming a number of extra instruments have been included in the *expanded* Decca aircraft equipment.

1) The Flight Plotter, which provides a simple method of transferring the hyperbola numbers shown on the instrument to the map. Such an aid is the absolute minimum requirement if even approximate use is to be made of the accuracy of the system in practical route flying.
2) The Flight Log is to a certain extent a development of the Flight Plotter. It automatically enters the track on a special map in perpendicular co-ordinates (abscissa formed by one family of hyperbolas, ordinate by the second), and is said to enable any desired course to be flown from this map reading. The special map is of a most unusual form, however, as its projection must be so selected that the two hyperbolas always intersect at right angles, so that in almost all regions, and particularly as distance from the transmitter increases, the scale is very much distorted, and such maps are quite useless for ordinary terrestrial navigation.
3) The Track Control Unit, like the course computer dial in the VOR system, shows deviation right or left of a given base line and the distance to or from the destination, thus attempting to give the pilot roughly those values which have been designated above as the values required in the basic system and which VOR, in conjunction with DME, provides as direct indicated values, for flight to or from the VOR, without conversion. As conversion instruments of this kind have a considerable amount of calculation to do, they are inevitably fairly heavy. The extra weight of the Flight Log is given as about 65 lbs. and for the Track Control Unit it will be higher. The weight of the Decca equipment in the aircraft, plus Flight Log, is 120 lbs., compared with 85 lbs. for the VOR/DME and 40 lbs. for the simple VOR equipment. The high measuring accuracy of the Decca equipment means that the multiple receiver (for simultaneous reception of four different frequencies) must be very sturdily built, so that it will inevitably be heavier than the VHF receiver for one reception channel only. Moreover, in making a comparison, it must be remembered that the VHF receiver is used not only for the VOR but also for the ILS and general radio communications, so that only a part of its weight should be counted in the VOR total.

A number of interesting suggestions has been made for using the Decca system for air traffic control. As such use presupposes the requirement of " flyability ", conversion instruments on board the aircraft are an essential. If advantage is to be taken of the system's accuracy there must be no delay in transmission of the hyperbolic co-ordinates from air to ground, so that special conversion instruments are required on the ground.

Conclusion

The *Decca system*, being a hyperbolic system, has greater accuracy and greater range (the latter regardless of altitude) than the polar co-ordinate systems i.e. Omnirange with DME. Its increased accuracy is, however, obtained at the expense of direct flyability, and means that complicated calculating equipment has to be carried. It is only by the use of this equipment that the pilot can obtain values from which he can fly, whereas in the polar co-ordinate system these values can be read off direct —and transmitted direct to the automatic pilot.

Experience in the USA has shown that the lower accuracy of the VOR/DME system is adequate even for the requirements of air traffic control in areas which have a high traffic density by today's standards. The adaptability of the VOR/DME system to air traffic control requirements is good, characterised by the good flyability of the system and the provision of readings in polar co-ordinates which correspond to the readings on the ATC ground instruments. Position reporting in hyperbolic co-ordinates, on the other hand, requires a good deal of calculation and conversion.

The greater range of the Decca system is achieved by the use of low frequencies. Range however is not a first requirement in short distance navigation. Adequate coverage can be obtained with VHF systems without excessive expense. It would therefore appear sensible to use LF systems only for long distance navigation, where there are few, if any, air traffic control requirements. Apart from the Decca a particularly useful system for this purpose appears to be the Consol, which admittedly is not so accurate, but requires less additional airborne equipment and only little ground equipment. The greater the accuracy of a LF system the less proof it is against voluntary or involuntary jamming by other transmitters. An advantage of the VHF systems is their low sensitivity to atmospheric interference and radiation disturbances, in particular where maximum reliability is required.

Yet another circumstance favours VHF navigation. In the above examination of the relationship between en route navigation systems and air traffic control the problem of communications and identification has been purposely ignored. The difficulties involved in the solution of these problems are greater and more extensive than those of en route navigation and can only be overcome by using decimeter waves, as it is only here that an adequate number of efficient transmission channels is available and it is possible to obtain separation in space by concentration of beams.

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An artist's impression of the new *Bell XHSL-1* to supplement our list of helicopters. This picture of the latest helicopter which is under construction for the American Naval Air Arm reached us just before we went to press. The Bell XHSL-1, which is to be used primarily for anti-submarine operations, is fitted with a 2440 h.p. Pratt & Whitney R-2800 " Double Wasp " engine and is to have a flying weight of 13,000 lbs. This is the first design in which Bell has departed from its favourite single-rotor construction (tail rotor for torque compensation) ; the XHSL-1 has two contra-rotating rotors in tandem with overlapping discs.

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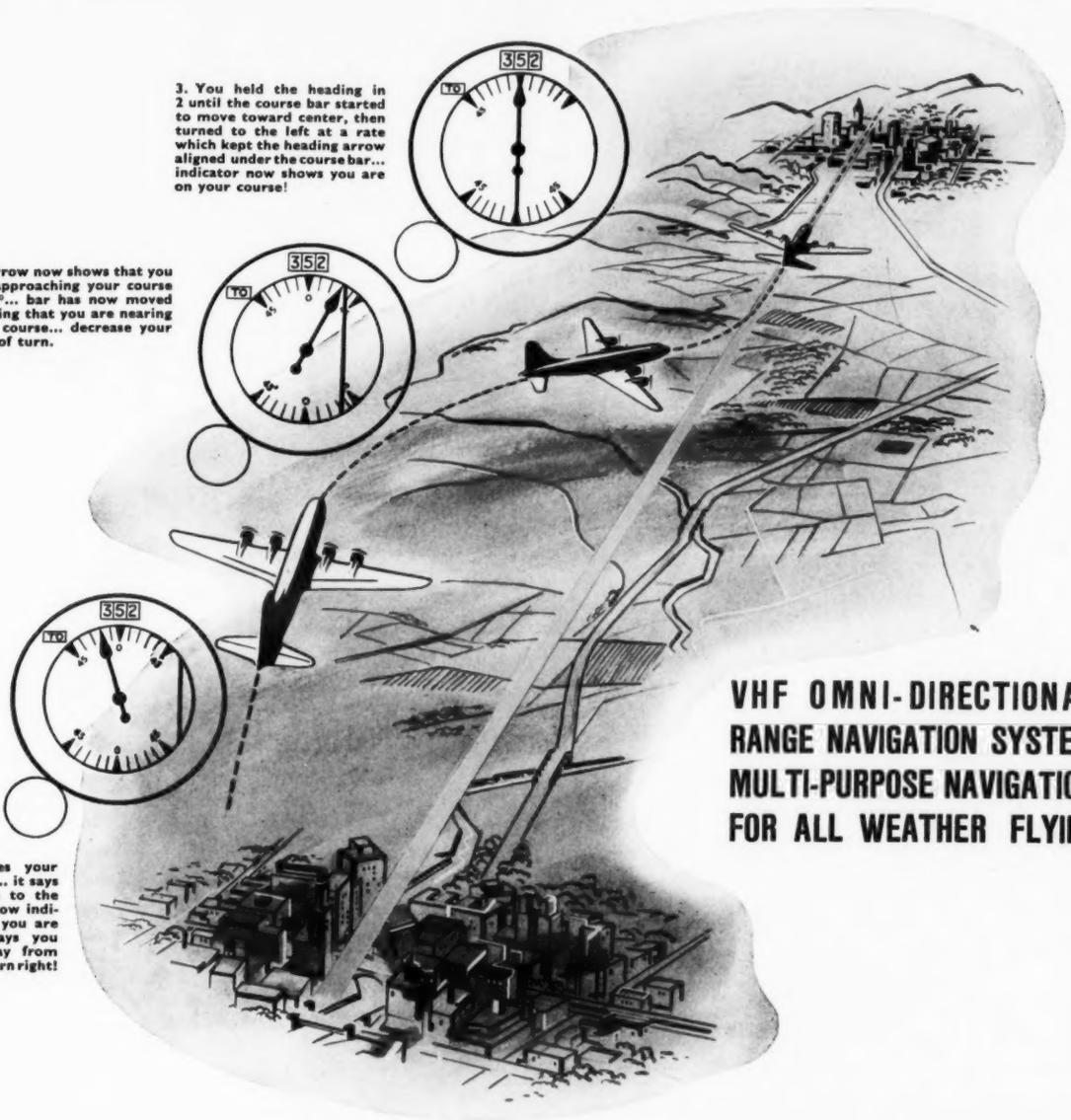
3. You held the heading in 2 until the course bar started to move toward center, then turned to the left at a rate which kept the heading arrow aligned under the course bar... indicator now shows you are on your course!
2. Arrow now shows that you are approaching your course at 45°... bar has now moved showing that you are nearing your course... decrease your rate of turn.
1. Bar indicates your desired course... it says your course is to the right. The arrow indicates the way you are headed... it says you are flying away from your course...turn right!
352
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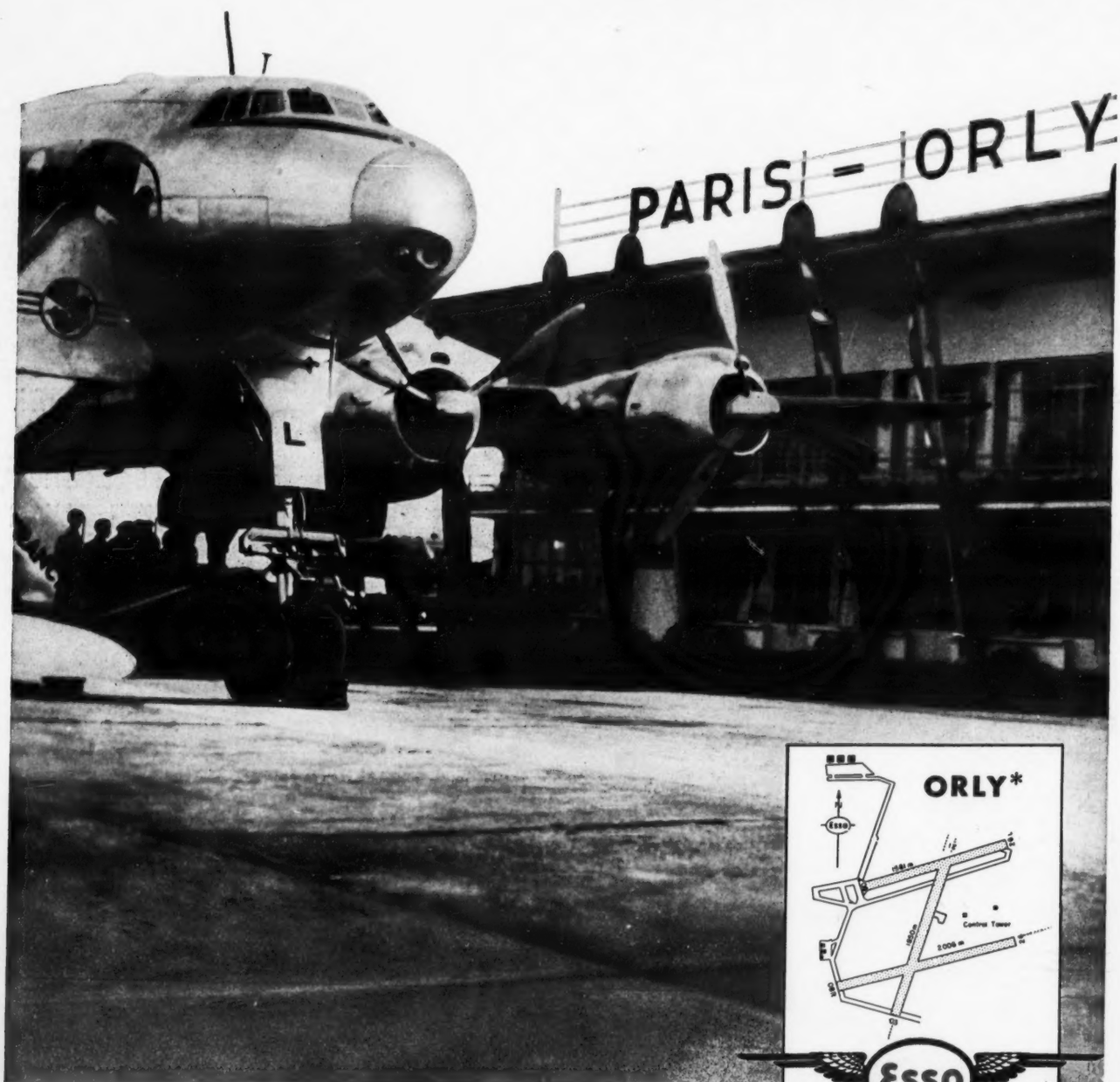

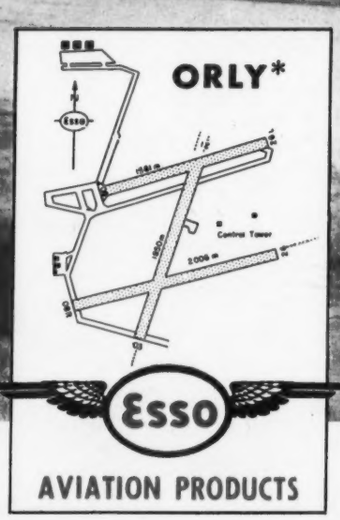

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